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Quality Assurance Project Plan

East Fork Lewis River Temperature and Fecal Coliform Bacteria Total Maximum Daily Load Study

by
Dustin Bilhimer, Lawrence Sullivan, and Stephanie Brock

Washington State Department of Ecology Environmental Assessment ProgramOlympia, Washington 98504-7710

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(Carol will add publication number and web address above)

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303(d) Listings Addressed in this Study:

Waterbody	Listing ID	New ID	Old Water Body ID (WBID)	Parameter	Year Listed
BREZEE CREEK	21992	WG95PJ		Fecal Coliform	2004*
LEWIS RIVER, E.F.	7818	E160MF	WA-27-2030	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	7815	E160MF	WA-27-2020	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	166771	E160MF	WA-27-2020	Fecal Coliform	1996
LOCKWOOD CREEK	7819	YD45JI	WA-27-2024	Fecal Coliform	1998, 1996
McCORMICK CREEK	7822	GF76XA	WA-27-2022	Fecal Coliform	1998, 1996
ROCK CREEK (NORTH)	7824	XD64JB	WA-27-2026	Fecal Coliform	1998, 1996
ROCK CREEK (NORTH)	21995	XD64JB	WA-27-2026	Fecal Coliform	1996, 2004*
ROCK CREEK (SOUTH)	7825	MI81KO	WA-27-2034	Fecal Coliform	1998, 1996
YACOLT CREEK	7826	KS71ST	WA-27-2032	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	6588	E160MF	WA-27-2020	Temperature	1998, 1996, 2004*
LEWIS RIVER, E.F.	37824	EI60MF	WA-27-2020	Temperature	2004*

* Proposed on draft 2004 list

EIM User Study ID: EFLRTMDL

Approvals

______________________________________ ______________

Dave Howard, TMDL Lead, SWRO Date

______________________________________ ______________

Kim McKee, Unit Supervisor, SWRO Date

Kelly Susewind, Section Manager, SWRO Date

Stephanie Brock, Project Manager, Nonpoint Studies Unit Date

Date

Dustin Bilhimer, Temperature Principal Investigator, Nonpoint Studies Unit

Lawrence Sullivan, Bacteria Principle Investigator, Watershed Studies Unit Date

Barb Carey, Hydrogeologist, Nonpoint Studies Unit Date

Karol Erickson, Unit Supervisor, Watershed Studies Unit Date

Darrel Anderson, Unit Supervisor, Nonpoint Studies Unit Date

Will Kendra, Section Manager, Watershed Ecology Section Date

Stuart Magoon, Director, Manchester Environmental Laboratory Date

Cliff Kirchmer, Ecology Quality Assurance Officer, EAP Date

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Abstract

Section 303(d) of the federal Clean Water Act requires the State of Washington to prepare a list of all surface waters in the state for which beneficial uses of the water are impaired by pollutants. Waterbodies placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs) to identify and quantify sources of the impairments and to recommend implementation strategies for reducing point and nonpoint source loads.

The East Fork Lewis River and its tributaries are listed on the 303(d) list of impaired water bodies for high instream temperatures and fecal coliform bacteria problems. This Quality Assurance (QA) Project Plan describes the technical study that will evaluate pollutants in those impaired waterbodies and build on previous data collection efforts conducted by a variety of governmental and private organizations. The study will be conducted by the Washington State Department of Ecology (Ecology) Environmental Assessment (EA) Program.

Introduction

The East Fork Lewis River and its tributaries lie within Water Resource Inventory Area (WRIA) 27 in southwestern Washington. The study area extends west from the boundary with Skamania County and the Gifford Pinchot National Forest boundary through Lewis County to the confluence with the North Fork of the Lewis River (Figure 1). The study area includes 12 waterbody segments impaired by fecal coliform and heat, as listed in the 1996 or 1998 Clean Water Act Section 303(d) lists. The impairments were identified based on sampling conducted by Lewis County, Ecology, and other entities.

Ecology is required by the federal Clean Water Act to conduct a TMDL study for all waterbodies on the 303(d) list. Studies begin with a technical evaluation of the current condition of the waterbodies including the capacity to absorb pollutants and still meet water quality standards. The study identifies and quantifies the likely sources of pollutants and determines how much pollution from point sources and nonpoint sources can contribute to a waterbody without exceeding standards. The outcome is a recommendation for point source wasteload allocations and nonpoint source load allocations, the sum of which cannot exceed the capacity of the waterbodies minus a margin of safety for each parameter of concern. The results of the technical study will be incorporated into a TMDL submittal report compiled by the Ecology regional office for approval by the U.S. Environmental Protection Agency (EPA). The subsequent report includes plans for implementing load and wasteload reductions developed in conjunction with other governments and agencies, as well as local citizens.

Project Objectives

Temperature

Characterize stream temperatures and processes governing the thermal regime in the East Fork Lewis River including the influence of tributaries, lakes, and wetlands on the heat budget.

Develop predictive models of the East Fork Lewis River system under critical conditions. Apply the models to determine load allocations for effective shade and other surrogate measures to meet temperature water quality standards, identify the areas influenced by lakes and wetlands, and if necessary determine the natural temperature regime.

Fecal Coliform Bacteria

Characterize fecal coliform bacteria concentrations and identify major sources (geographically or by land use) to the East Fork Lewis River, Jenny Creek, McCormick Creek, Brezee Creek, Lockwood Creek, Mason Creek, Rock Creek North, Yacolt Creek and Rock Creek South.

Determine fecal coliform TMDL targets for the East Fork Lewis River and its tributaries achieved through point source wasteload allocations and nonpoint source load allocations.

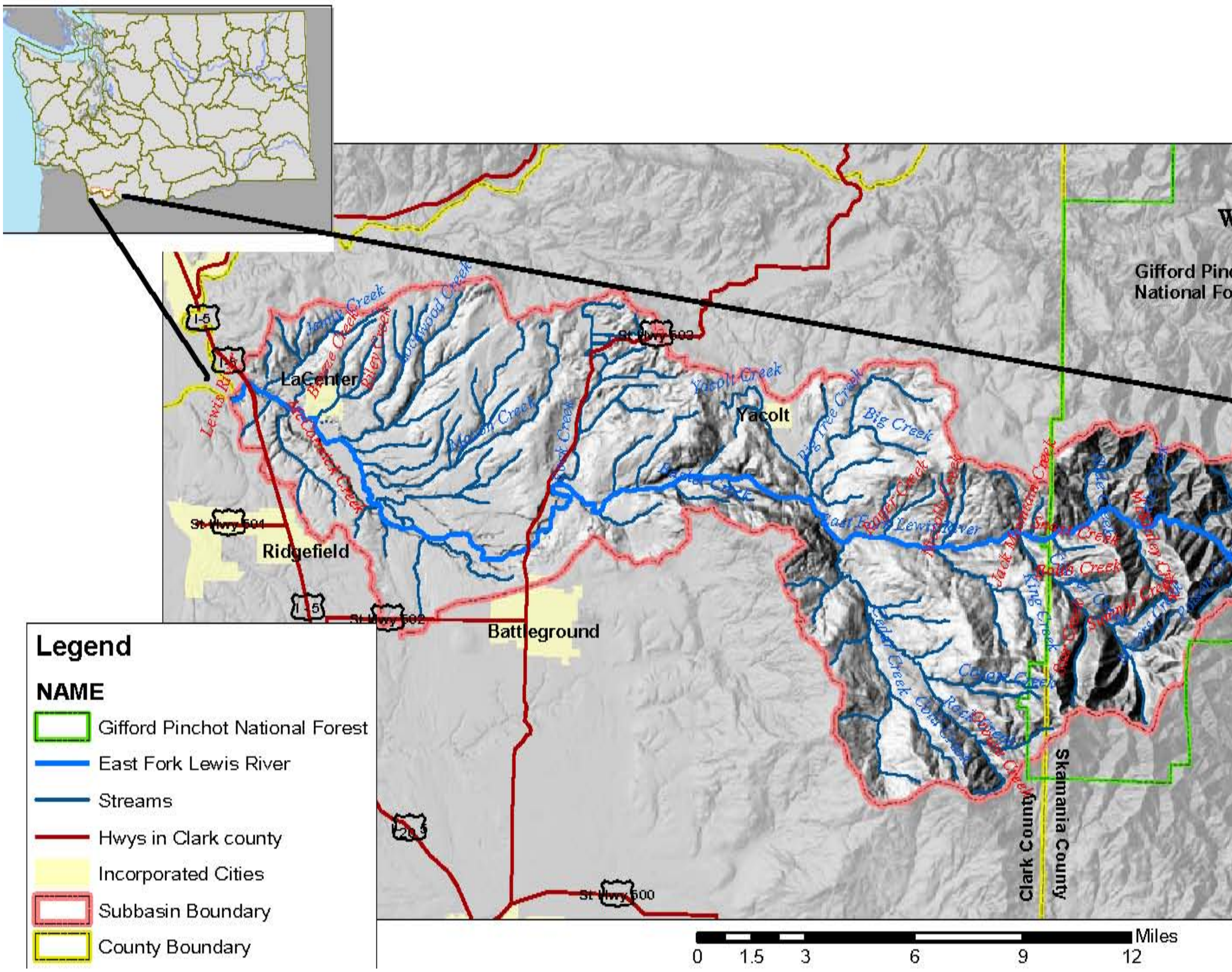


Figure 1. East Fork Lewis River Subbasin

Water Quality Standards

The Department of Ecology completed two 303(d) listing cycles in 1996 and 1998 and is currently finishing the 2004 list. The new listing process includes "listing categories" 1 through 5. Category 5 listings are considered impairments to be addressed by a TMDL study. Category 2 listings are designated as "waters of concern" because the data collected for these segments during list development had an insufficient number of data points to evaluate or complied with some but not all portions of the water quality standard it was being evaluated for. Therefore, there is some indication of potential water quality problems and these listings should be used to aid TMDL development. Table 1 shows the current and proposed 303(d) listings for the East Fork Lewis River subbasin.

Table 1. 303(d) listings for the East Fork Lewis River and its Tributaries (shaded cells indicate Category 2 listings)

Waterbody	Listing ID	New ID	Old Water Body ID (WBID)	Parameter	Category	Year of 303(d) listing	Description	Year of listing data
BREZEE CREEK	21992	WG95PJ		Fecal Coliform	5	2004	Upstream of LaCenter bottoms bridge	2002
LEWIS RIVER, E.F.	7818	E160MF	WA-27-2030	Fecal Coliform	5	1998, 1996	Moulton Falls Station	1991, 1992
LEWIS RIVER, E.F.	7815	E160MF	WA-27-2020	Fecal Coliform	5	1998, 1996	Pollack Road	1991, 1992
LEWIS RIVER, E.F.	166771	E160MF	WA-27-2020	Fecal Coliform	5	1996	Ambient WQ station	1994, 1995
LOCKWOOD CREEK	7819	YD45JI	WA-27-2024	Fecal Coliform	5	1998, 1996	Lockwood Cr Rd station	1991, 1992
McCORMICK CREEK	7822	GF76XA	WA-27-2022	Fecal Coliform	5	1998, 1996	NW LaCenter Rd station	1991, 1992
ROCK CREEK (NORTH)	7824	XD64JB	WA-27-2026	Fecal Coliform	5	1998, 1996	NE Rock Cr Rd station	1991, 1992
ROCK CREEK (NORTH)	21995	XD64JB	WA-27-2026	Fecal Coliform	5	1996, 2004	Rock Cr North upstrm of Gabriel Road	2002
ROCK CREEK (SOUTH)	7825	MI81KO	WA-27-2034	Fecal Coliform	5	1998, 1996	Dole Valley Rd station	1991, 1992
YACOLT CREEK	7826	KS71ST	WA-27-2032	Fecal Coliform	5	1998, 1996	NE Railroad Ave station	1991, 1992
LEWIS RIVER, E.F.	6588	E160MF	WA-27-2020	Temperature	5	1998, 1996, 2004	Ambient WQ station 27D090	1991, 1996, 2001-2004
LEWIS RIVER, E.F.	37824	EI60MF	WA-27-2020	Temperature	5	2004	EF Lewis above Nicholls Creek	1997, 1999-2002
ROCK CREEK (NORTH)	22003	XD64JB	WA-27-2026	Dissolved Oxygen	2	2004	Rock Cr North upstrm of Gabriel Road	2002
COPPER CREEK	11756	SP80TK		pH	2	2004	EMAP station R0CE99-116	2000
LEWIS RIVER, E.F.	7817	E160MF	WA-27-2020	Temperature	2	1998, 1996	Pollack Road	1991, 1992
LOCKWOOD CREEK	7820	YD45JI	WA-27-2024	Temperature	2		Lockwood Cr Rd station	1992
McCORMICK CREEK	7821	GF76XA	WA-27-2022	Temperature	2	1998, 1996	NW LaCenter Rd station	1991, 1992

Under Washington Administrative Code 173-201A-130 the East Fork Lewis River is classified as Class AA (Extraordinary Waters) from Moulton Falls (river mile 24.6) to the headwaters in the Gifford Pinchot National Forest. Downstream of Moulton Falls to the confluence with the North Fork Lewis River the East Fork Lewis River is classified as Class A (Excellent Waters). These classifications define the applicable temperature and bacteria criteria for waters within these reaches.

The EPA is currently reviewing Ecology's proposed water quality rule revisions that will replace the 1997 standards following federal approval. In the proposed rule revision, the waterbody classification system is replaced by a beneficial-use based designation. Under the new rule, waterbodies are required to meet water quality standards based on the beneficial uses of the waterbody. The most current information and status on this revision can be found at http://www.ecy.wa.gov/programs/wq/swqs/rev_rule.html.

Beneficial Uses

The proposed water quality standards establish beneficial uses of waters and incorporate specific numeric and narrative criteria for parameters such as water temperature and fecal coliform bacteria. The criteria are intended to define the level of protection necessary to support the beneficial uses. The beneficial uses of the waters in the East Fork Lewis River basin are:

Core and non-core fish habitat: These two designations refer to the quality of the spawning and rearing habitat. These will be very similar to the Class AA and A designations for extraordinary and excellent waters.

Recreation: The recreational opportunities on the East Fork Lewis River include fishing, swimming, and boating in both the Class A and AA designated waters.

Municipal and Agricultural Water Supply and Stock Watering: Agriculture extracts water for irrigation and stock watering, and all drinking water comes from two highly productive aquifers in this subbasin.

Miscellaneous Uses (Wildlife Habitat): Riparian areas are used by a variety of resident and migratory aquatic and terrestrial wildlife.

Temperature Water Quality Criteria

Temperature is a water quality concern because most aquatic organisms, including salmonids, are cold blooded and are strongly influenced by water temperature (Schuett-Hames et al., 1999). Temperature, habitat, and floodplain connectivity are major concerns in the East Fork Lewis River and its tributaries because of the use of its waters by steelhead and bull trout, which are listed as a threatened species under the Endangered Species Act. Elevated temperature and altered channel morphology resulting from various land-use activities such as gravel mining, flood control, agriculture, and existing geologic and flow conditions limit available spawning and rearing habitat for salmonids.

The 1997 water quality standards (currently in effect) for temperature are as follows:

- Class AA: Freshwater temperature shall not exceed 16.0°C due to human activities. When natural conditions exceed 16.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Incremental temperature increases resulting from point source activities shall not, at any time, exceed $t=23/(T+5)$[1].

[1] T represents the background waterbody temperature, while t is maximum permissible temperature increase measured at the edge of the mixing zone; both are in °C.

Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C when the temperatures are less than the standard.

- Class A: Water temperature shall not exceed 18.0°C due to human activities. When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C. Incremental temperature increases resulting from point source activities shall not, at any time, exceed $t=28/(T+7)$[1]. Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.

The proposed revised temperature criterion would change from a daily maximum to a 7-day average temperature value and would depend upon specific fish presence. A discussion of the proposed water quality rules can be found at: http://www.ecy.wa.gov/programs/wq/swqs/rev_rule.html.

Bacteria Water Quality Criteria

The water quality standards for bacteria are as follows:

Class AA: Freshwater fecal coliform organism levels shall both not exceed a geometric mean[2] value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.

Class A: Freshwater fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.

The proposed new water quality standards would not change these criteria.

[2] The geometric mean is calculated as the n[th] root of the product of n numbers.

Background

Historical Data Review

The East Fork Lewis River subbasin has been extensively studied by many groups because of its importance for fish resources and its high potential for salmon recovery. A summary of the available data sources is provided below.

Ecology Ambient Monitoring Station at Daybreak Park

Ecology's Environmental Assessment Program maintains a water quality monitoring station on the mainstem East Fork Lewis River at the bridge crossing in Daybreak Park (River Mile 10.2). Water quality monitoring began in 1977 and continuous instream temperature monitoring was added in June 2001. Temperature data for this station is summarized in Table 2 and fecal coliform data in Table 2.

Table 2. Temperature data from Ambient Water Quality Monitoring Station, 27D090, on the East Fork Lewis River at Daybreak Park.

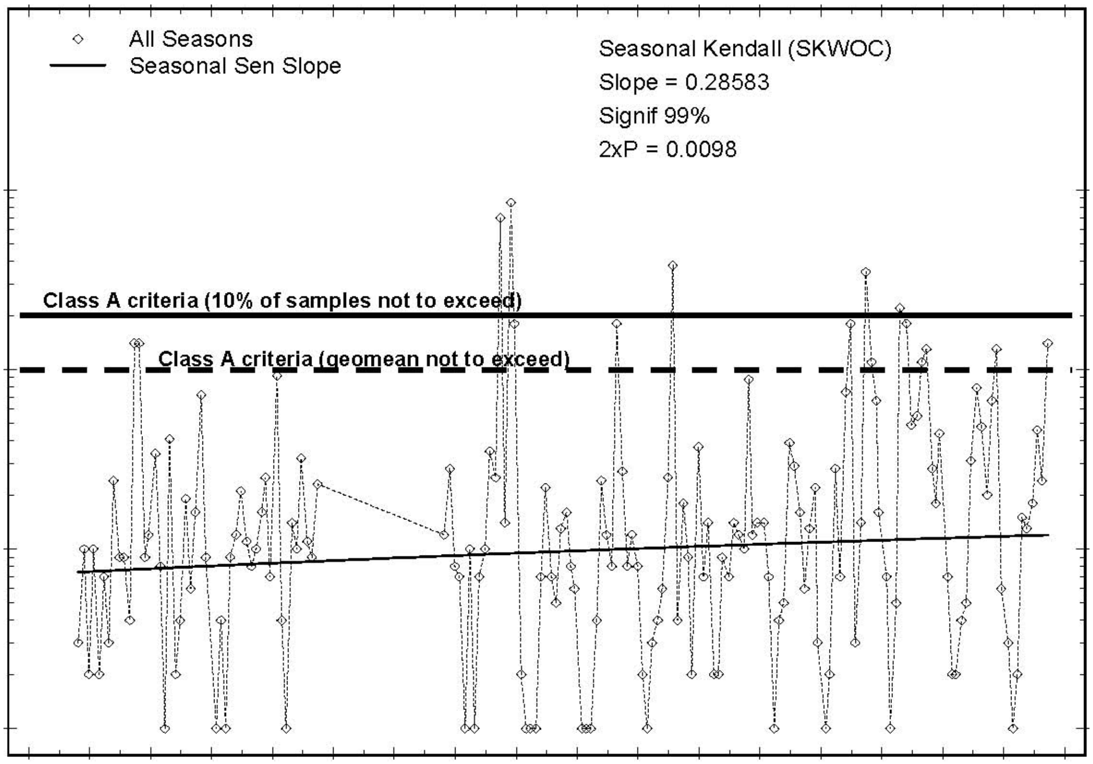
Temperature Exceedences					
date	**time**	**units**	**criterion**	**result**	**% exceed**
8/18/2004	9:20	deg C	18	20.8	16
7/21/2004	10:22	deg C	18	19.1	6
7/23/2003	10:35	deg C	18	21.5	19
8/29/2001	16:32	deg C	18	21.5	19
7/25/2001	17:18	deg C	18	21.8	21
8/29/2000	16:05	deg C	18	19.3	7
6/27/2000	16:45	deg C	18	18.8	4
8/25/1999	15:10	deg C	18	20.8	16
7/28/1999	16:00	deg C	18	20.8	16
8/25/1998	15:20	deg C	18	18.6	3
7/28/1998	16:10	deg C	18	25	39
7/28/1997	14:50	deg C	18	20.2	12

Seasonal Temperature Maxima (°C)						
Year	**Constituent**	**Criterion**	**Max 1-day temp**	**Date/Time[a]**	**Max 7-day temp**	**Date[b]**
2003	Air Temp	NA	38.2	7/30/2003 16:30	34.6	9/2/2003
2003	Water Temp	18	27	7/30/2003 17:00	25.9	7/29/2003
2002	Air Temp	NA	40.0	8/13/2002 16:30	33.8	8/14/2002
2002	Water Temp	18	25.0	8/13/2002 17:00	23.9	8/15/2002
2001	Air Temp	NA	35	8/9/2001 16:30	30.6	8/9/2001
2001	Water Temp	18	25.1	8/10/2001 17:00	24.4	8/10/2001

[a] There may be other dates with the same maximum. Only the first date is shown for any given year. [b]

Date corresponds to the midpoint of the 7-day rolling average (day 4)

The ambient monitoring station has a record of monthly fecal coliform data from 1988 through 2004. A Seasonal Kendal (SKWOC) trend analysis was performed using WQHydro Software (Aroner, 1994) to determine the historic trend. Results of the trend analysis, provided in Figure 2, has a slope of 0.29 and a significance of 99%. These results indicate a statistically significant increase in bacteria levels over the period of record (1988-2004). Additionally, a trend analysis performed on data collected during 1994-2004 had a slope of 0.69 and a significance of 99% which also indicates a rise in bacteria levels during this period.



East Fork Lewis Ambient Station Log Plot

All Seasons
Seasonal Kendall (SKWOC)

Seasonal Sen Slope Slope = 0.28583 Signif 99% 2xP = 0.0098

1000

Class A criteria (10% of samples not to exceed)

200

Class A criteria (geomean not to exceed)

100

20

10

2

1

888990 9192 93 9495 9697 98 9900 01020304

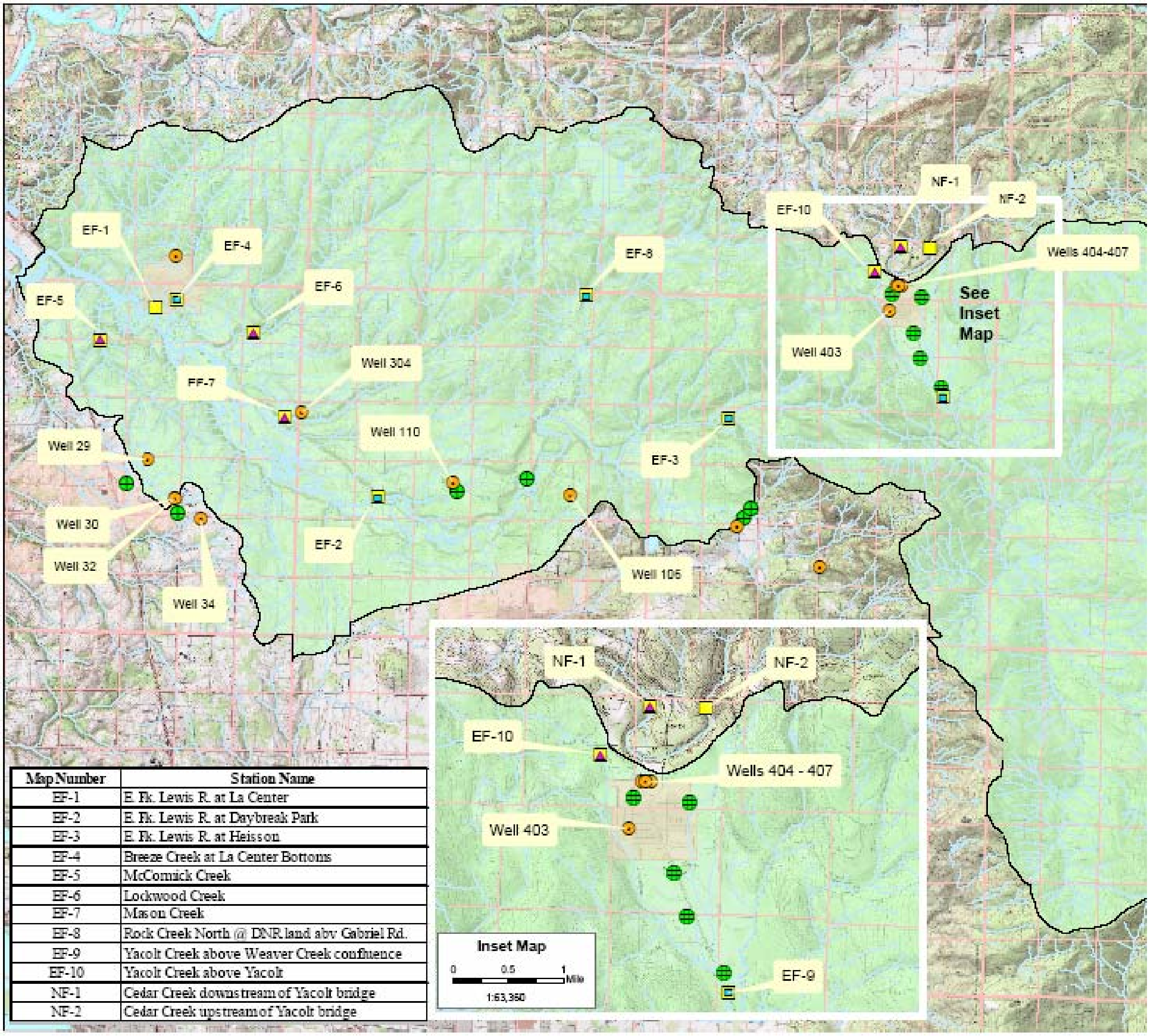
YEAR

Figure 2. Fecal Coliform Trend Analysis of data collected at Ecology's Ambient Monitoring Station

Clark County Public Utilities Water Quality Monitoring

The Clark County Public Utilities Department (Clark PUD) has collected monthly grab samples of fecal coliform and measured instantaneous stream temperature at 8 stations within the East Fork Lewis watershed since summer 2003. Figure 3 provides a map of the sampling locations. Table 3 provides the summary statistics for the fecal coliform data, including 90^{th} percentile, geometric mean, and the maximum measured values.

Fecal Coliform (#/100mL)



Map Number	Station Name
EF-1	E. Fk. Lewis R. at La Center
EF-2	E. Fk. Lewis R. at Daybreak Park
EF-3	E. Fk. Lewis R. at Heisson
EF-4	Breeze Creek at La Center Bottoms
EF-5	McCormick Creek
EF-6	Lockwood Creek
EF-7	Mason Creek
EF-8	Rock Creek North @ DNR land abv Gabriel Rd.
EF-9	Yacolt Creek above Weaver Creek confluence
EF-10	Yacolt Creek above Yacolt
NF-1	Cedar Creek downstream of Yacolt bridge
NF-2	Cedar Creek upstream of Yacolt bridge

Figure 3. Map of Clark County PUD's Fecal Coliform Monitoring Sites

The fecal coliform data was summarized for the following three time periods: annual, dry and wet season. The dry season was defined as data collected during the months of June through October and the wet season as data collected during November through May. The stations located on the East Fork Lewis, McCormick Creek, Lockwood Creek and Mason Creek are classified as Class A waters (applicable fecal coliform criteria: geometric mean of 100 cfu/100 mL and not more than 10% of samples to exceed 200 cfu/100 mL). The two stations located on Yacolt Creek are classified as Class AA (geometric mean of 50 cfu/100 ml and not more than 10% of samples to exceed 100 cfu/100 mL).

Data indicate that the mainstem East Fork Lewis River meets the Class A fecal coliform water quality criterion during all seasons. McCormick Creek and Mason Creek show impairment throughout all seasons. Lockwood Creek shows impairment during the dry season. Lower Yacolt Creek meets Class AA fecal coliform standards throughout the year. However, Upper Yacolt Creek shows impairment during the dry season.

Table 3. Summary Statistics for Clark PUD Fecal Coliform Data (collected monthly from July 2003 - October 2004)

geometric mean WQ criteria (geo-mean) Maximum90th percentile WQ criteria (10% sample exceedance) Impairment Sample size	McCormick Crk (EF-5) Annual Dry Wet (cfu / 100 mL) 175 226 135 100 100 100 5000 1600 5000 1586 1374 1875 200 200 200 YES YES YES 16 8 8	EFL at La Center (EF-1) Annual Dry Wet (cfu / 100 mL) 10 10 12 100 100 100 50 50 50 41 38 50 200 200 200 NO NO NO 15 8 7	Lockwood Crk (EF-6) Annual Dry Wet (cfu / 100 mL) 69 188 25 100 100 100 900 900 240 477 903 97 200 200 200 YES YES NO 16 8 8	Mason Crk (EF-7) Annual Dry Wet (cfu / 100 mL) 39 62 45 100 100 100 900 900 866 332 790 598 200 200 200 YES YES YES 14 8 6

geometric mean WQ criteria (geo-mean) maximum90th percentile WQ criteria (10% sample exceedance) Impairment Sample size	EFL at Daybreak (EF-2 ECY station) Annual Dry Wet (cfu / 100 mL) 11 23 7 100 100 100 850 700 850 74 109 41 200 200 200 NO NO NO 167 70 97	EFL at Heisson (EF-3) Annual Dry Wet (cfu / 100 mL) 10 17 5 100 100 100 80 80 23 50 86 22 200 200 200 NO NO NO 14 7 7	Lower Yacolt Crk (EF-9) Annual Dry Wet (cfu / 100 mL) 16 28 8 50 50 50 130 130 23 63 85 28 100 100 100 NO NO NO 15 8 7	Upper Yacolt Crk (EF-10) Annual Dry Wet (cfu / 100 mL) 15 30 7 50 50 50 110 110 23 86 133 33 100 100 100 NO YES NO 13 7 6

Dry defined as June through October

Wet defined as November through May

The temperature data displayed in Figures 4 and 5 represent instantaneous instream temperature measurements collected by Clark PUD during monthly site visits conducted between July 2003 and January 2005. Figure 4 compares the data collected at stations located below Moulton Falls (classified as Class A waters) to the $18^{\circ}C$ water quality criterion. The graph illustrates that all of the stations, with the exception of Lockwood and Mason Creek, exceed the $18^{\circ}C$ temperature criterion at some point during the summer (June, July or August). Lockwood and Mason Creek may exceed the 18°C criterion during the summer months; however, the data collected by Clark PUD does not illustrate this exceedance because all of the temperature checks were performed at these sites prior to noon. Therefore, the maximum temperature at these sites was not measured.

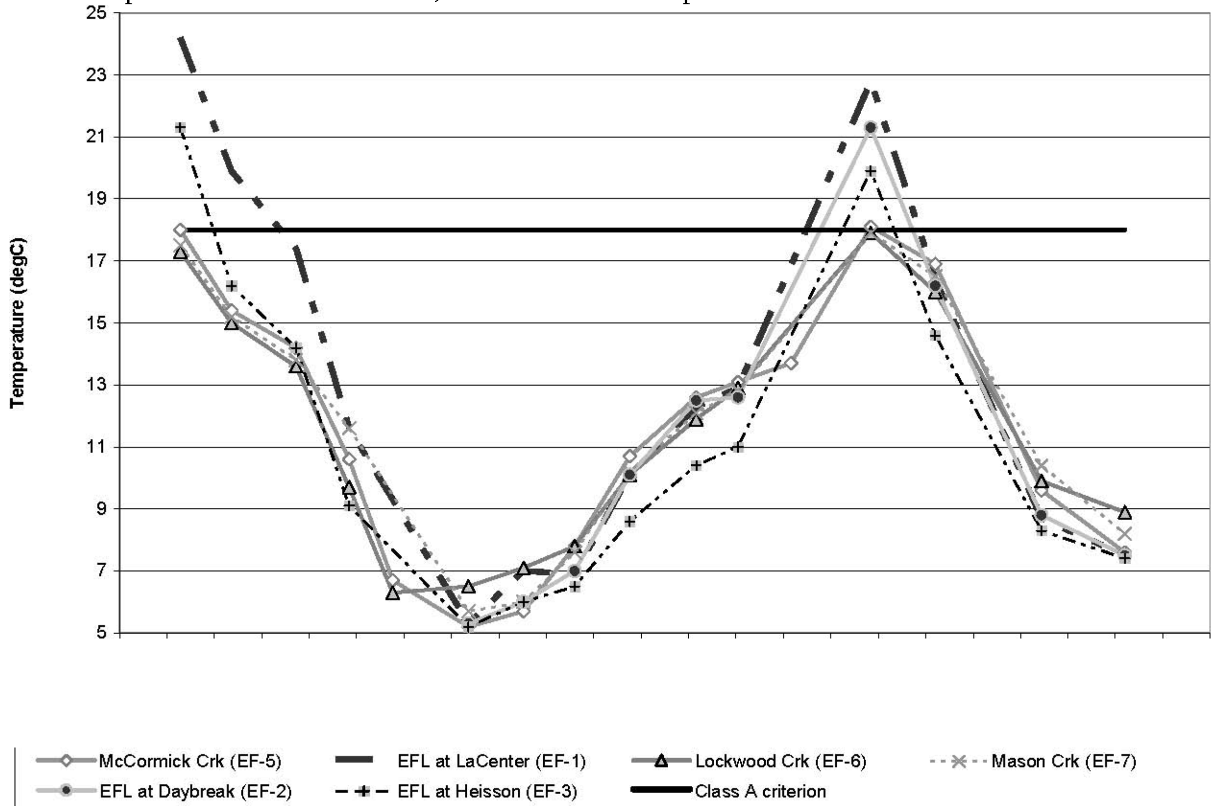
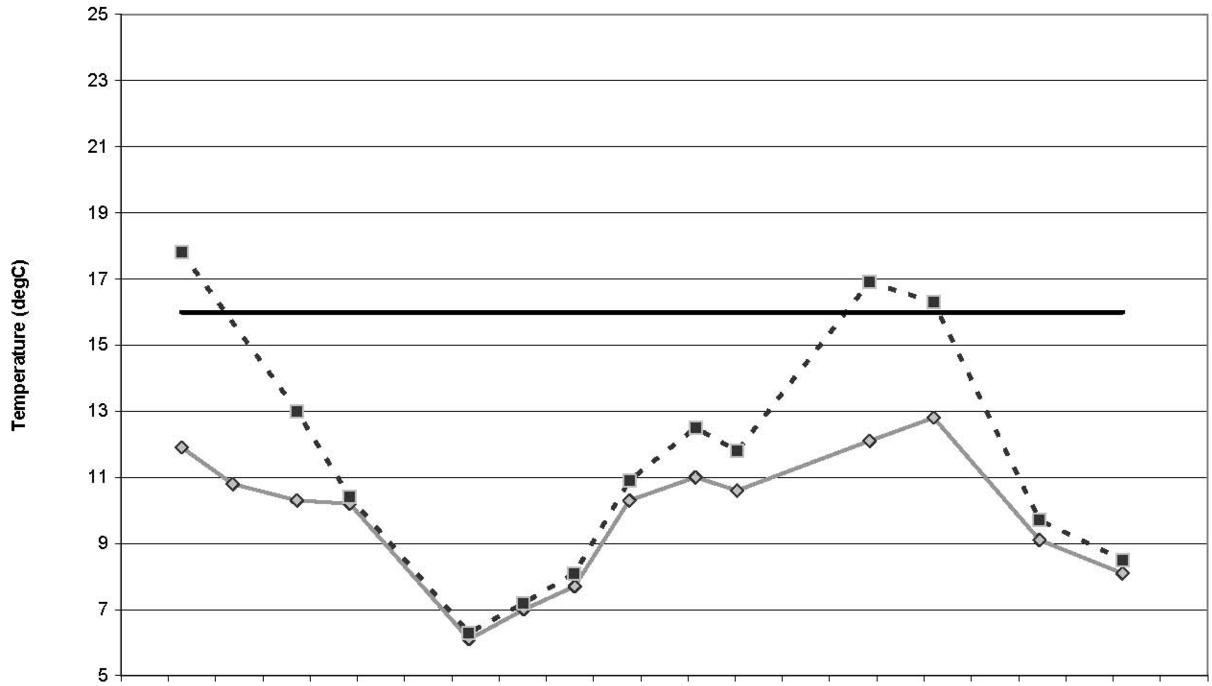


Figure 4. Temperature profiles of Clark PUD stations located in Class A streams

Figure 5 illustrates the temperature profiles of the two Clark PUD stations located above Moulton Falls (classified as Class AA) compared to the 16°C stream temperature criterion. Data collected at Lower Yacolt Creek indicates that the stream is in compliance with Class AA water temperature criterion at all times. However, data collected at Upper Yacolt Creek exceeds the 16°C water temperature standard during the summer months (June, July, or August).

Figure 5. Temperature profiles of Clark PUD stations located in Class AA streams



25
23
21
19
17
15
13
11
9
7
5
Temperature (degC)

Clark County Water Quality Monitoring
The Clark County Water Resources Program has monitored water quality at various locations within the East Fork Lewis River basin since 1992. However, only the data collected since 2002 was available in electronic format and was analyzed and summarized for this QA Project Plan. Figure 6 provides a diagram of Clark County water quality sampling locations. In the following paragraphs, the water quality data collected at stations Rock Creek North (RCN050), Brezee Creek (BRZ010), and Jenny Creek (JEN010) is presented and discussed. Data for the other stations labeled on the map was collected by the Clark County Public Utilities Department and was presented and discussed in the previous section.

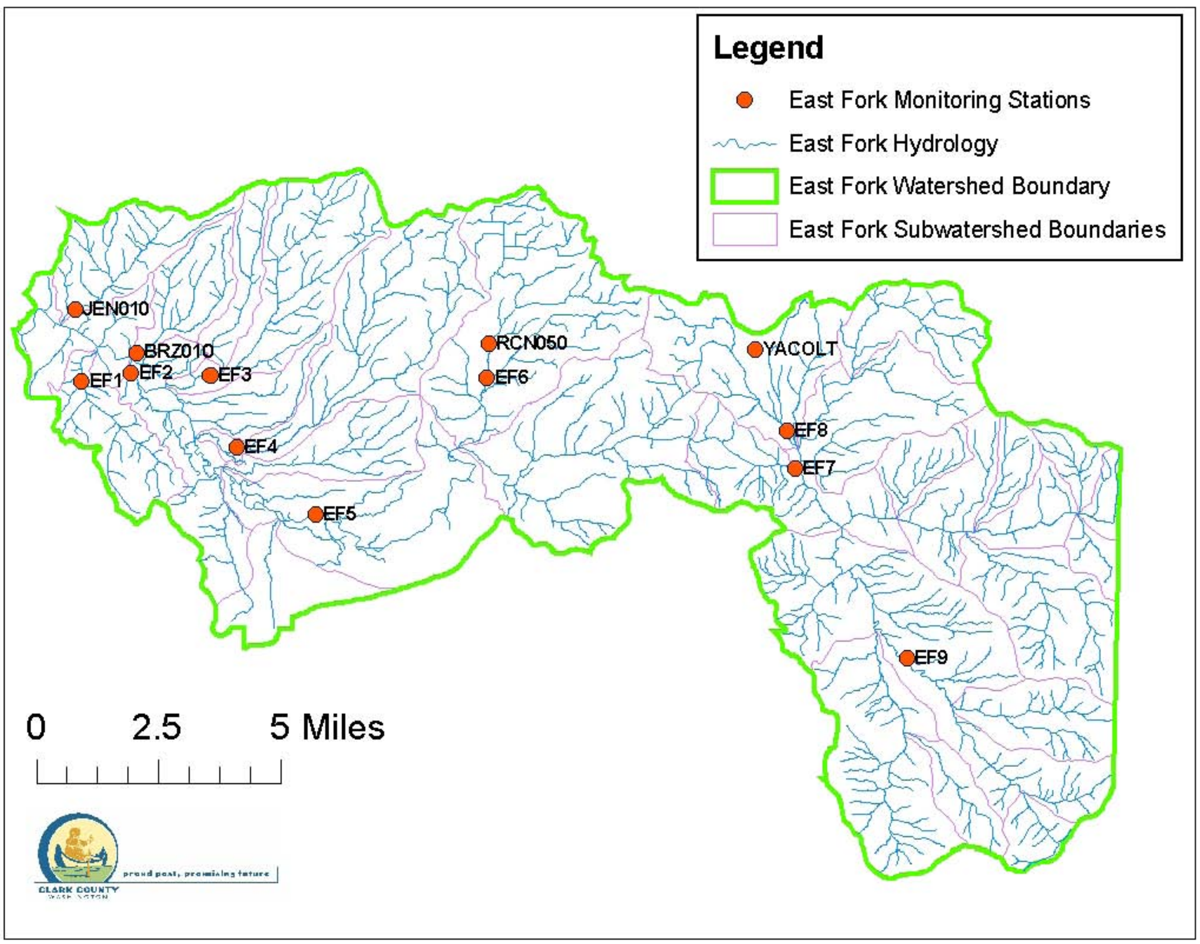


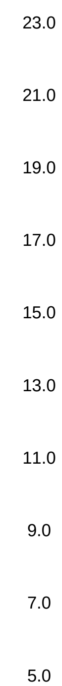
Figure 6. Clark County Water Quality Monitoring Stations

Data collected by Clark County for Brezee Creek, Rock Creek North and Jenny Creek (all Class A waters) are summarized for the annual, dry and wet season (Table 4). Brezee Creek and Rock Creek North are impaired throughout all seasons. Data collected on Jenny Creek were too limited to analyze seasonally; however, the available data indicates that the stream is impaired.

Table 4. Summary Statistics for Clark County Fecal Coliform Data

	Brezee Crk (BRZ010)			Rock Crk North (RCN050)			Jenny Crk (JEN010)		
	Annual	Dry	Wet	Annual	Dry	Wet	Annual	Dry	Wet
	(cfu / 100 mL)			(cfu / 100 mL)			(cfu / 100 mL)		
geometric mean	203	439	103	33	93	15	58	too few data points to calculate seasonal statistics	
WQ criteria (geo-mean)	100	100	100	100	100	100	100		
max	7500	7500	1600	1600	300	1600	500		
90th percentile	1792	2070	1047	319	300	168	300		
WQ criteria (10% sample exceedance)	200	200	200	200	200	200	200		
Impairment	YES	YES	YES	YES	YES	NO	YES		
Sample size	30	14	16	30	13	17	5		

The temperature data displayed in Figure 7 represent the maximum daily instream temperature measurements collected by Clark County using continuous temperature data loggers during the low-flow periods (June-October) of 2002 through 2004. The data illustrate that temperatures on Brezee Creek, Rock Creek North and Jenny Creek consistently exceed the Class A (18°C) water quality criterion during low-flow summer conditions.



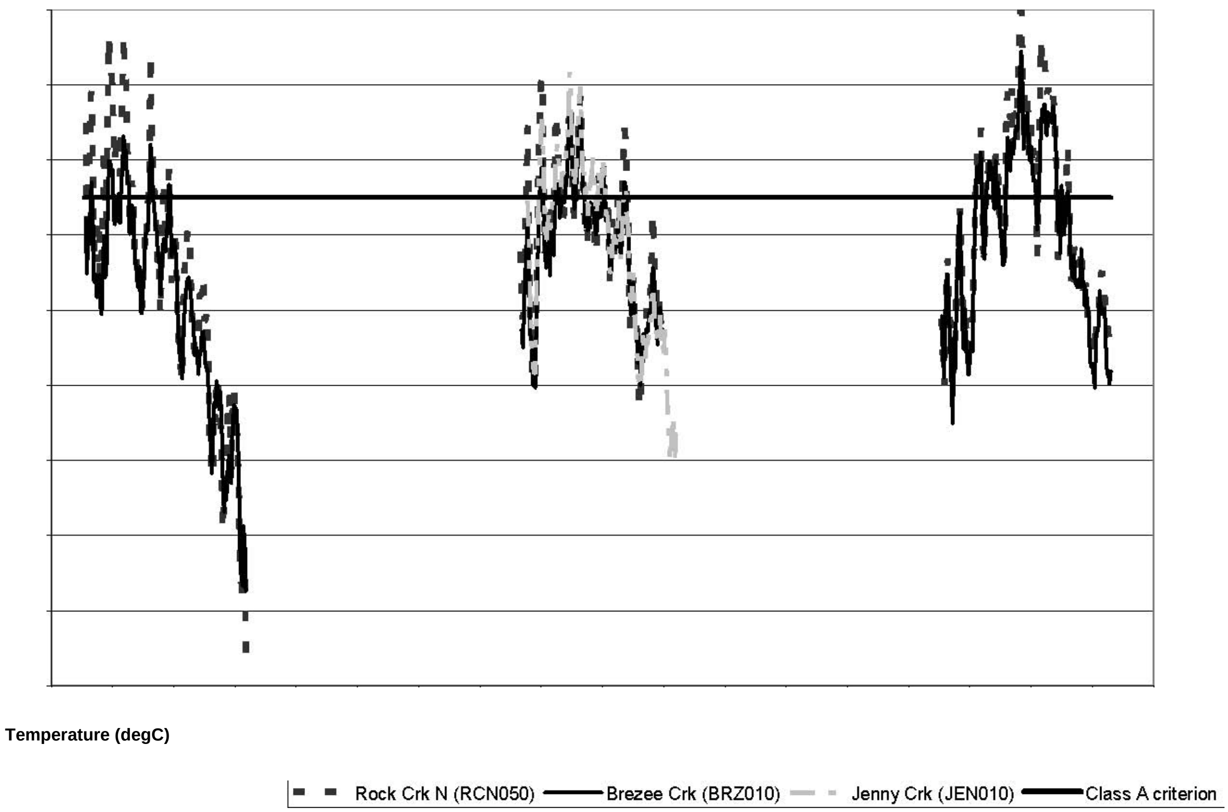


Figure 7. Maximum daily temperature profiles for Clark County temperature sampling sites.

Channel Assessment by Friends of the East Fork Lewis River

The Friends of the East Fork Lewis River (FOEF) established and collected data for various channel transects on the mainstem East Fork Lewis River. The purpose of the channel transects was development of a strategic plan for stream channel enhancements by Friends of the East Fork Lewis River (Dover Habitat Restoration LLC, 2003). The assessment's proposed stream channel enhancements will not be evaluated in this TMDL technical study. However, channel transect measurements will be used to provide channel geometry data during model development if the FOEF field measurements meet our data quality objectives for this study. Friends of the East Fork may survey the same transects during the summer 2005 field season (pers. comm. with Richard Dyrland, 8 March 2005).

USGS

The US Geological Service (USGS) has operated a continuous streamflow gage on the East Fork Lewis River near Heisson Rd (# 14222500) from 1929 to present. Its location is at the downstream end of the bedrock formations that dominate the streambed material in the upper East Fork Lewis River and at the head of the unconsolidated deposits. The average annual discharge based on the entire period of record is 735 cubic feet per second (cfs). This streamflow gage will be included in the streamflow monitoring network established for this TMDL study.

Watershed Management Plan

A Watershed Management Plan was prepared for Water Resource Inventory Area (WRIA) 27 by the WRIA 27 Planning Unit (HDR and EES, 2004). The WRIA 27 Planning Unit includes representatives from the Lower Columbia Fish Recovery Board, Lewis County, Skamania County, Washington Department of Fish and Wildlife, Washington Department of Ecology, and others who worked together from 1999 through 2004. Plan objectives relate to:

1 Protecting or enhancing conditions in the watershed,
2 Developing and implementing the Watershed Plan, and
3 Improving information and data management.

The plan makes recommendations in five key areas: water supply, stream flow, surface water quality, groundwater quality, and habitat. In water quality, the watershed plan recommends the development of TMDLs. Specifically, the plan states the East Fork Lewis River should be the priority subbasin for TMDL development in both WRIA 27 and 28. The plan also presents a series of subbasin plans, including the East Fork Lewis River subbasin, focused on local conditions and detailed implementation strategies (HDR and EES, 2004).

Gifford Pinchot National Forest Temperature TMDL

During the spring and summer of 2005, Ecology's Water Quality Program will be completing a temperature TMDL for the Gifford Pinchot National Forest using data collected by the US Forest Service. The study will only examine waterbodies within the forest boundary. The study area for the Gifford Pinchot National Forest Temperature TMDL spans from the headwaters of the East Fork Lewis River to the Forest Service boundary located at the Sunset Falls Campground (RM 32.5). Load allocations and management recommendations developed as part of the Gifford Pinchot National Forest Temperature TMDL will assist in the development and establishment of boundary condtions for this TMDL.

Lower Columbia Fish Recovery Board

Several studies have been funded by the Lower Columbia Fish Recovery Board to study groundwater/surface water interactions and habitat in the East Fork Lewis River Watershed. These studies include:

Salmon-Washougal & Lewis Watershed Management Plan WRIAs 27-28 (HDR and EES, 2004)

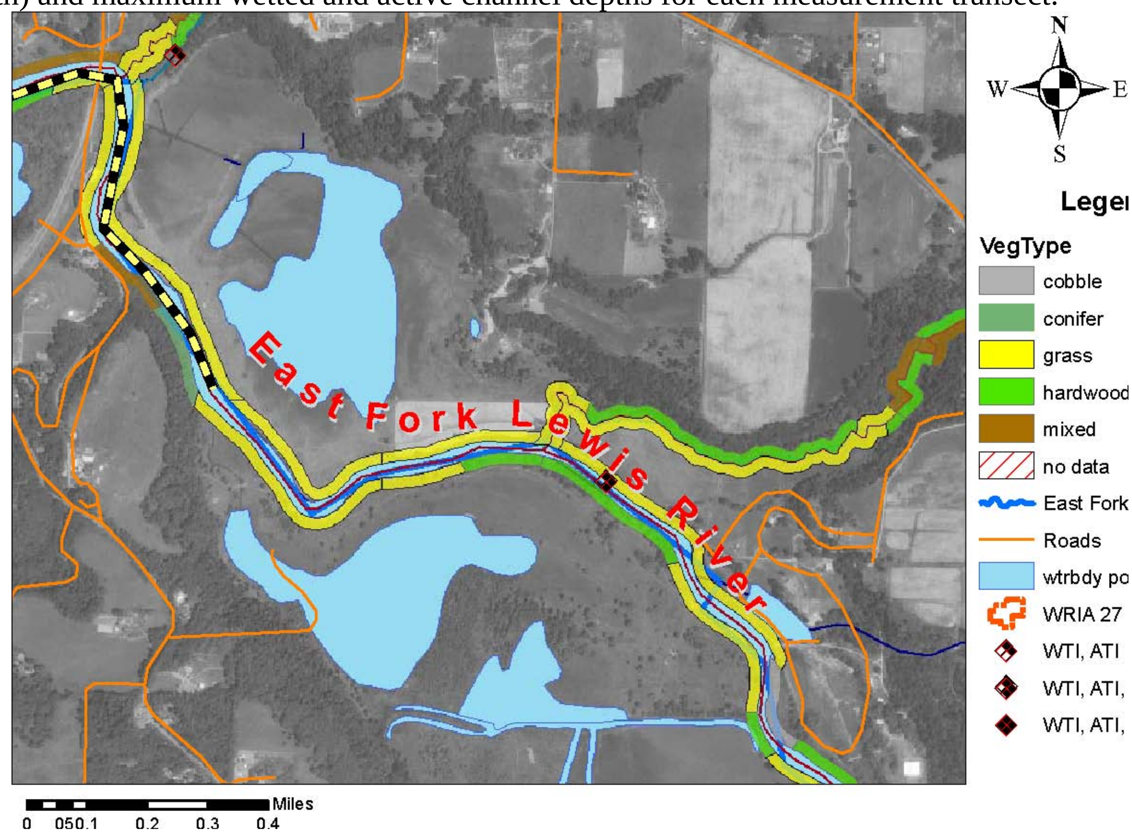
East Fork Lewis River habitat assessments (Keefe et al., 2004 and Johnston et al., 2005)

An examination of groundwater/surface water relationships for tributaries to the East Fork (PGG, 2003).

Information from these studies was used to help design the TMDL study. Selected information will be used to fill some of the temperature data requirements itemized in the Data Management Procedures section of this QA Project Plan. Some of the most applicable data are described below.

In 2003, seepage runs (streamflow measurements made at the same time at numerous sites) were performed on the following tributaries to the East Fork Lewis River and their tributaries: Brezee Creek, Dean Creek, McCormick Creek, Lockwood Creek, Mason Creek, Yacolt Creek, Jenny Creek, Rock Creek North, and several unnamed tributaries. Gaining and losing reaches were identified for each of these small systems and hydraulic connection between the regional groundwater system and the East Fork Lewis River and its tributaries were assessed. The study found that the majority of baseflow in the East Fork Lewis River and floodplain flows directly to the mainstem East Fork Lewis River from the deeper aquifers, rather than from tributaries fed by shallow aquifers (PGG, 2003). Data from this study has been used to guide the development of the sampling design for this TMDL.

A Level II Habitat Assessment on the East Fork Lewis River subbasin was recently completed and published (Keefe et al., 2004 and Johnston et al., 2005). The study methods followed the US Forest Service's Level I and II Stream Inventory Protocols for Region 6. The purpose of the assessment was to collect data on habitat conditions, riparian conditions, sediment sources, and hydromodifications for the mainstem East Fork Lewis River and other priority reaches identified in the report. The study products include GIS covers of channel migration zones and historic stream margins in the East Fork Lewis River valley, riparian vegetation maps for a 100-ft buffer around the East Fork Lewis River and its major tributaries (Figure 8), and floodplain alterations. Other data includes: sediment counts and percent distributions, riparian vegetation height and canopy density, stream gradients, wetted widths, active channel widths (equivalent to bankfull width) and maximum wetted and active channel depths for each measurement transect.



Legend

cobble conifer grass hardwood mixed no data East Fork Lewis River Roads wtrbdy polygon WRIA 27 Boundary WTI, ATI WTI, ATI, GWTI WTI, ATI, GWTI, RH

Figure 8. Riparian Habitat GIS layer

Project Description

Study Area

The East Fork Lewis River is one of the three major rivers located within WRIA 27, which also includes the North Fork Lewis and Kalama Rivers. The headwaters of the East Fork, which originate from a small alpine lake, flow out of the western crest of the Cascade Mountain range. Elevation at the headwater of the East Fork is 4,442 feet above mean sea level. The river flows 42 miles to its confluence with the North Fork Lewis River at an elevation of 4 feet below mean sea level (Figure 9). The East Fork is influenced by the tidal bulge from the Columbia River from its mouth to a short distance below Daybreak Park Bridge at approximately river mile 10.2 (PGG, 2003).

As mentioned in the Historic Data Review section, a temperature TMDL is currently under development for waterbodies located in the Gifford Pinchot National Forest boundaries. Therefore, this TMDL will focus its data collection, modeling and TMDL development efforts on the East Fork Lewis River from the National Forest boundary, at approximately river mile 32.5, to the confluence with the North Fork Lewis River. The Gifford Pinchot National Forest Boundary coincides with the Clark County-Skamania County line; therefore, the study area falls entirely in Clark County. River mile values for this project plan are derived from the USGS 7.5 minute quadrangles.

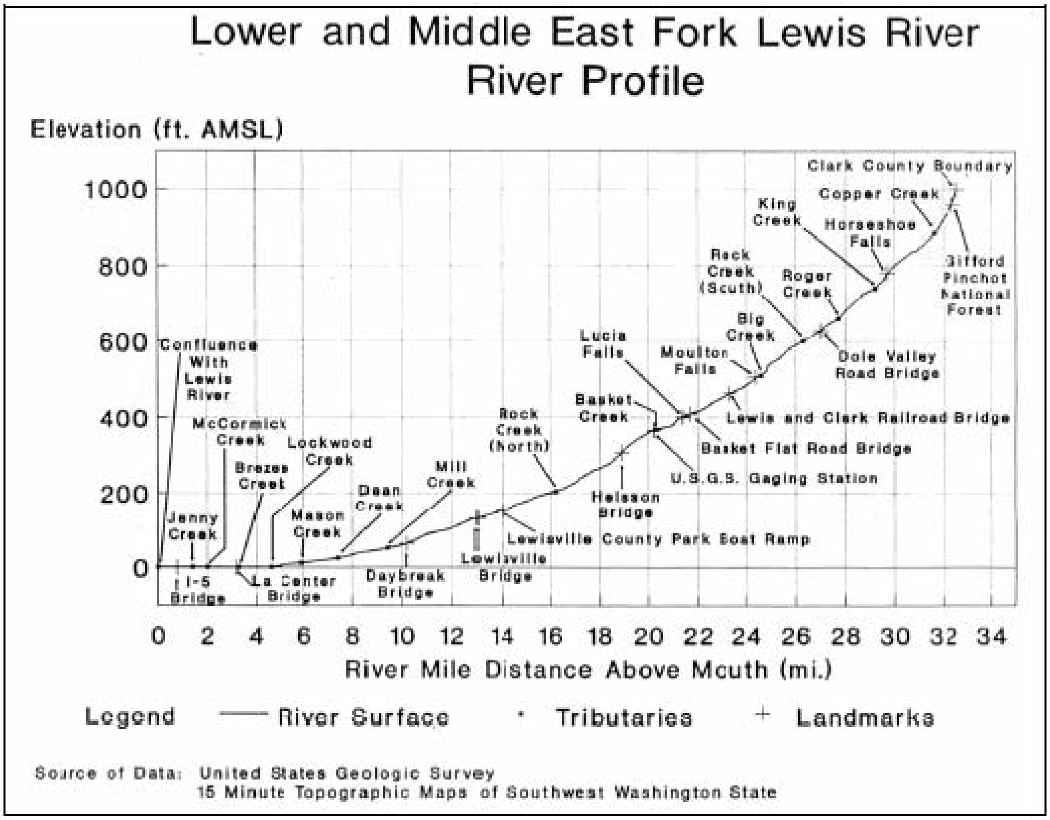


Figure 9. East Fork Lewis River Profile. Adapted from Hutton, 1995.

Fisheries Resources

The Habitat Limiting Factors Analysis (Wade, 2000) describes WRIA 27 as having generally poor riparian conditions, loss of off-channel habitat, and large woody debris below habitat standards. The East Fork Lewis River subbasin has critical fall Chinook and chum spawning habitat in the lower 10 miles of the mainstem (from Daybreak park to the mouth) and provides critical winter and summer steelhead spawning and rearing habitat above Sunset Falls and on Rock Creek (north). Table 5 describes the distribution of anadromous fish in this subbasin developed from data available on StreamNet.

Table 5. Anadromous Fish Distribution in the East Fork Lewis River Subbasin

Stream Name	Chum Salmon	Coho Salmon	Fall Chinook	Searun Cutthroat	Summer Steelhead	Winter Steelhead
Big Tree Creek		X		X	X	X
Brezee Creek		X				
Copper Creek					X	X
East Fork Lewis River	X	X	X	X	X	X
Green Fork				X	X	
King Creek					X	X
Little Creek					X	
Lockwood Creek		X				
Mason Creek		X			X	X
McCormick Creek		X				

McKinley Creek					X	
Poison Creek				X	X	
Rock Creek		X		X	X	X
Unnamed Trib to Rock Cr				X	X	X
Unnamed Trib 1		X				
Unnamed Trib 2		X				
Unnamed Trib 3						X
Unnamed Trib 4		X				
Unnamed Trib 5		X				

The limiting factors analysis considers elevated water temperatures as "a major problem in many tributaries and especially within the lower East Fork." Channel instability, diking, and development within the floodplain are also recognized as factors limiting the amount of rearing habitat during the summer for juvenile salmon and steelhead. According to the analysis, the mainstem migration (avulsion) into the abandoned Ridgefield pits have added to the channel instability and led to a significant loss in spawning habitat for fall chinook.

The only barriers to anadromous passage within the mainstem East Fork Lewis River are Lucia Falls (RM 21.5) and other natural falls upstream. Sunset Falls (Gifford Pinchot National Forest Boundary RM 32.7) was notched in 1982, opening up a significant amount of habitat in the upper watershed. Steelhead are the only species that consistently migrate past Lucia Falls. The following tributaries have known access problems for anadromous fish species: McCormick Creek, Brezee Creek, Lockwood Creek, Mason Creek, and Dean Creek. Details on the identified barriers are given in Wade (2000).

Current Land Use Patterns

The East Fork Lewis River subbasin drains 212 square miles of which approximately 167 square miles are within Clark County. The portion of the basin located within Clark County comprises the study area for this TMDL. A TMDL for the remainder of the subbasin, which falls within Skamania County, is being developed in the Gifford Pinchot National Forest study by Ecology. Clark County owns approximately 1,679 acres (2.6 square miles) of riparian land throughout much of the lower East Fork Lewis River valley. The majority of the land consists of large parcels on the south side of the river where the land is designated as park land. The publicly owned parcels include:

LaCenter Bottoms Stewardship Site which offers 3,500 feet of shoreline on the East Fork Lewis, a 0.66 mile walking trail and wildlife viewing opportunities
Lewisville Park with campgrounds and facilities
Daybreak Park with fishing access
Lucia Falls Park which prohibits water contact to protect sensitive spawning grounds
Moulton Falls Park that offers day-use recreation and water contact opportunities

The East Fork Lewis River Greenway, which spans from the river mouth to Daybreak Park, is state-designated priority habitat and has large concentrations of migratory waterfowl, wintering bald eagles, and high-quality riparian habitat.

The East Fork Lewis River subbasin includes the towns of Yacolt and LaCenter. The majority of the land throughout the subbasin is privately owned. Major public land ownership is shown in Figure 10. Data used to produce Figure 10 originated from the Washington State Department of Natural Resources major public lands survey (2000) and the Lewis River Habitat Assessment (Johnston et al., 2005). The state owned land and privately managed forests are primarily used for active timber management and many harvest cuts are visible from the road.

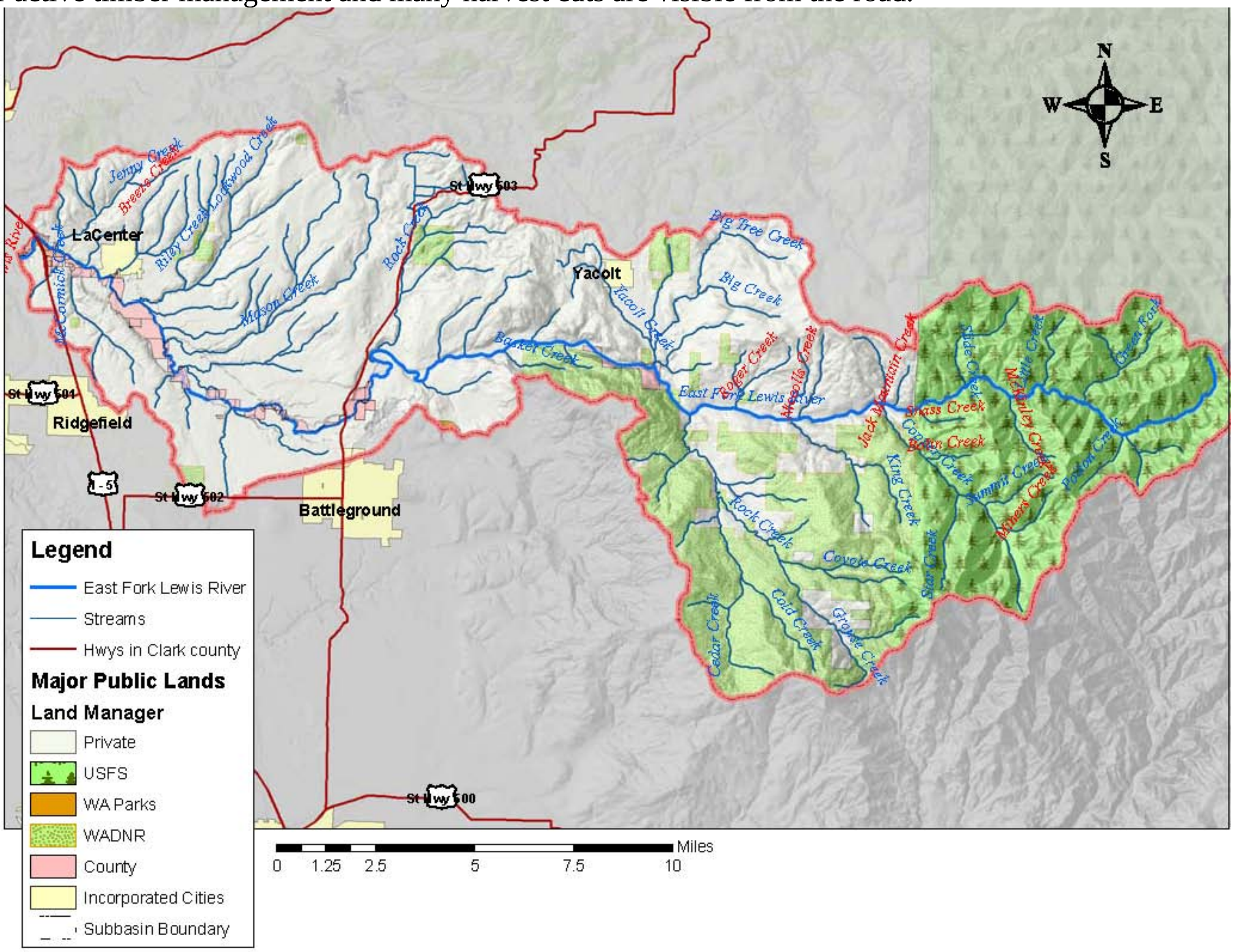


Figure 10. Land Ownership Map

Miles

0 1.25 2.5 5 7.5 10

Land use patterns within the study area fall into two sections:

1. Lower section from the mouth to the USGS gauge near Heisson Rd (river mile 20.3)

Most of the increase in population and anthropogenic activity occurs in the lower section of the watershed. Clark County experienced a 49% increase in population between 1970 and

1990. This was the largest population growth experienced in Washington State during this time period (GeoEngineers, 2001). Most of this growth is due to an increase in new residents who commute to work in Vancouver and Portland. Commercial and hobby farms and rural and suburban residential land use dominate this lower section.

2 Upper section from the stream gauge (river mile 20.3) to the Gifford Pinchot National Forest Boundary (river mile 32.5)

The upper section of the watershed is affected more by timber management practices than by rural development. Forests in this upper section burned many times in the first half of the 20th century and salvage logging from these fires removed much of the large woody debris recruits along the riparian area and stream channel from 1930 through the 1960s (Wade, 2000).

Hydrogeology and Hydrology

The headwaters of the East Fork Lewis River originate on the western slope of the Cascades and receive most of their baseflow from groundwater. The upper part of the subbasin, from approximately river mile 19.7, consists of substrate comprised primarily of andesite and other older rocks of volcanic origin. There is limited unconsolidated material in the streambed and the bedrock is exposed in many places. The upper subbasin (as defined for this study approximately from river mile 19.7 to 32.5) consists of V-shaped valleys with steep banks that confine stream channels and restrict lateral movement.

The East Fork Lewis River downstream of Heisson Rd cuts through the Lower Troutdale gravel aquifer which overlays the larger undifferentiated fine-grained sediments of Pliocene origin. These layers are topped by a layer of unconsolidated materials consisting of Pleistocene sediments that were washed down during catastrophic floods of the Columbia River and Holocene pyroclastic debris deposits. The unconsolidated layer is a highly productive aquifer (USGS, 1990).

The USGS has maintained a streamflow gauge near Heisson Road with a historical record going back to 1929 (Figure 11). The minimum peak annual flow for seven consecutive days that has a recurrence interval of ten years (7Q10) is 38 cfs based on the period of record from 1929-2003. The minimum peak annual flow for seven consecutive days that has a recurrence interval of two years (7Q2) is 51.1 cfs based on the period of record from 1929 to 1979 (Williams and Pearson, 1985). Low summer baseflows typically occur during late July through August and peak flows occur during storm events in October through June.

Simple Box Plot of Streamflow Measurements for East Fork Lewis River Near Heisson, WAUSGS gage #14222500 (period of record 1929-2003)

Discharge (cubic feet per second) Logarithmic Scale

100000

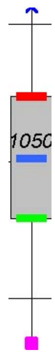
(1996)(1972) 21000

12300

(1931) (1999) (1933)15600

13500

(1931) 10800



(1951)

7000 **(1949)** **(1985)**

5560

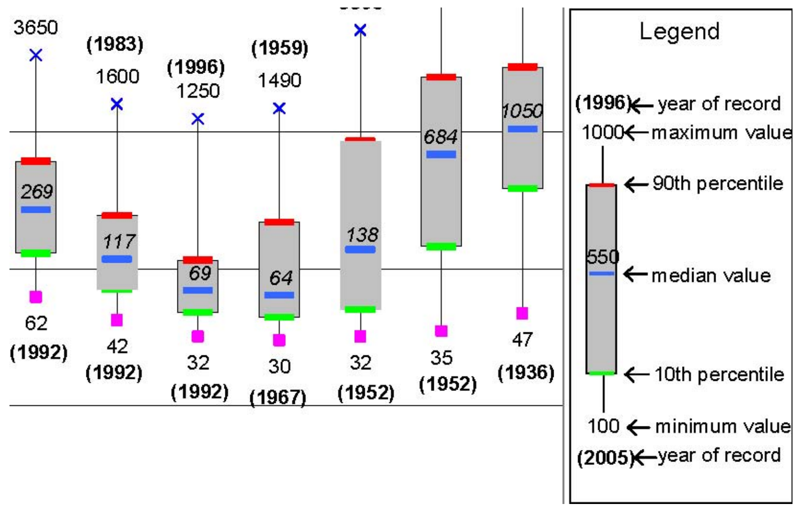
10000

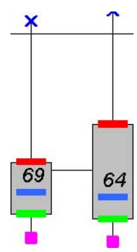
3750 3650

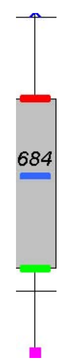
(1983) **(1959)** 1600

(1996) 1490 1250

1000 160 172 180 189 100


3650
(1983)
1600
(1996)
1250
(1959)
1490
269
117
69
64
138
684
1050
62
(1992)
42
(1992)
32
(1992)
30
(1967)
32
(1952)
35
(1952)
47
(1936)
Legend
(1996) ← year of record
1000 ← maximum value
← 90th percentile
550 ← median value
← 10th percentile
100 ← minimum value
(2005) ← year of record


69
64


684


138

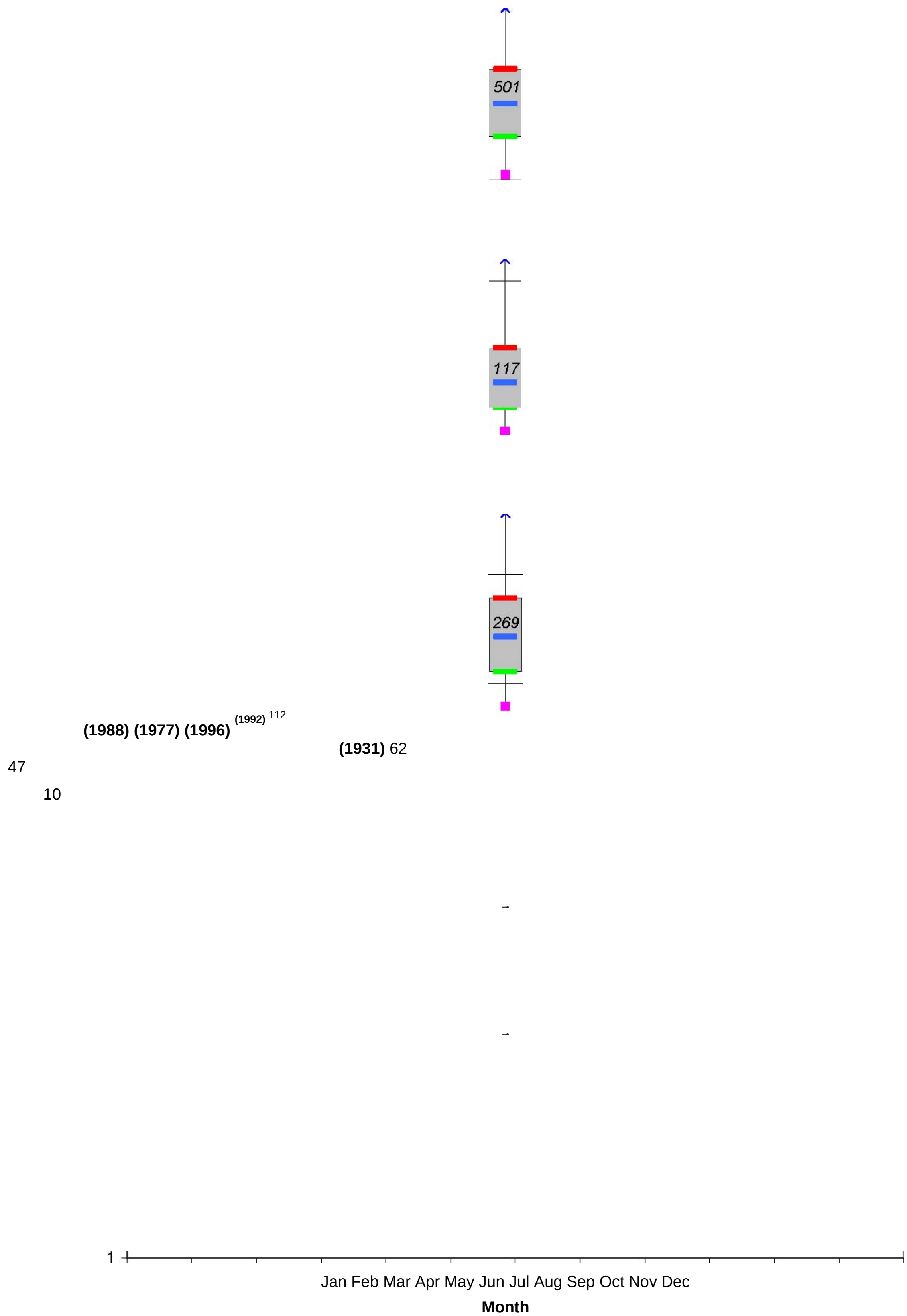


Figure 11. Hydrograph for Gage #14222500 at Heisson Road. Each line represents one year's data.

The Habitat Limiting Factors report (Wade, 2000) estimates that over 50% of the off-channel habitat and associated wetlands within the floodplains of the lower East Fork have been disconnected from the river. This conversion of the channel from braided to a mostly single channel morphology has substantially reduced the complexity of habitat and largely eliminated side channel and backwater habitats that were historic salmon and steelhead spawning and rearing grounds.

The lower 6-miles of the stream channel has a naturally high rate of lateral migration and the main channel of the East Fork Lewis River has meandered quite a bit within its channel migration zone as seen in Figure 12. The following channel modifications, identified by Wade (2000), Delk and Dyrland (2005), and Johnston et al. (2005), have contributed to destabilizing the stream channel:

An old right angle dike at the Clark County Maintenance Facility (~RM 9) and subsequent erosion and bedload from the cliffs the river was forced into.

Dikes on the north side of the river at LaCenter bottoms (RM 3.3-4.5).

Dikes along the lower end of Lockwood Creek.

A number of dikes that disconnect the river from the floodplain on County owned properties along the south side of the river from RM 4.5 to RM 7. Drainage ditches drain wetlands and channels in this area that help replenish groundwater throughout the year and provide overwintering habitat for coho juveniles.

Remnant/discontinuous dikes that run along the north side of the river across from the Ridgefield Pits near RM 8.

Remnant dikes that run along the County's property (referred to as the Zimmerly property) just downstream of the Ridgefield Pits near RM 7, reducing the connection between the river and downstream wetland and floodplain habitat.

Dikes that run along the north side of the river downstream of Dean Creek (near RM 7.2) to protect properties from flooding.

Remnant dikes that are left in mid-channel around the old RM 9 gravel pit.

Daybreak Dike, located on the south side of the river upstream from Daybreak Park near RM 12, disconnecting a large overflow channel with floodplain habitat from the river.

- Remnant/discontinuous dikes that run along the north side of the river across from the Ridgefield Pits near RM 8.
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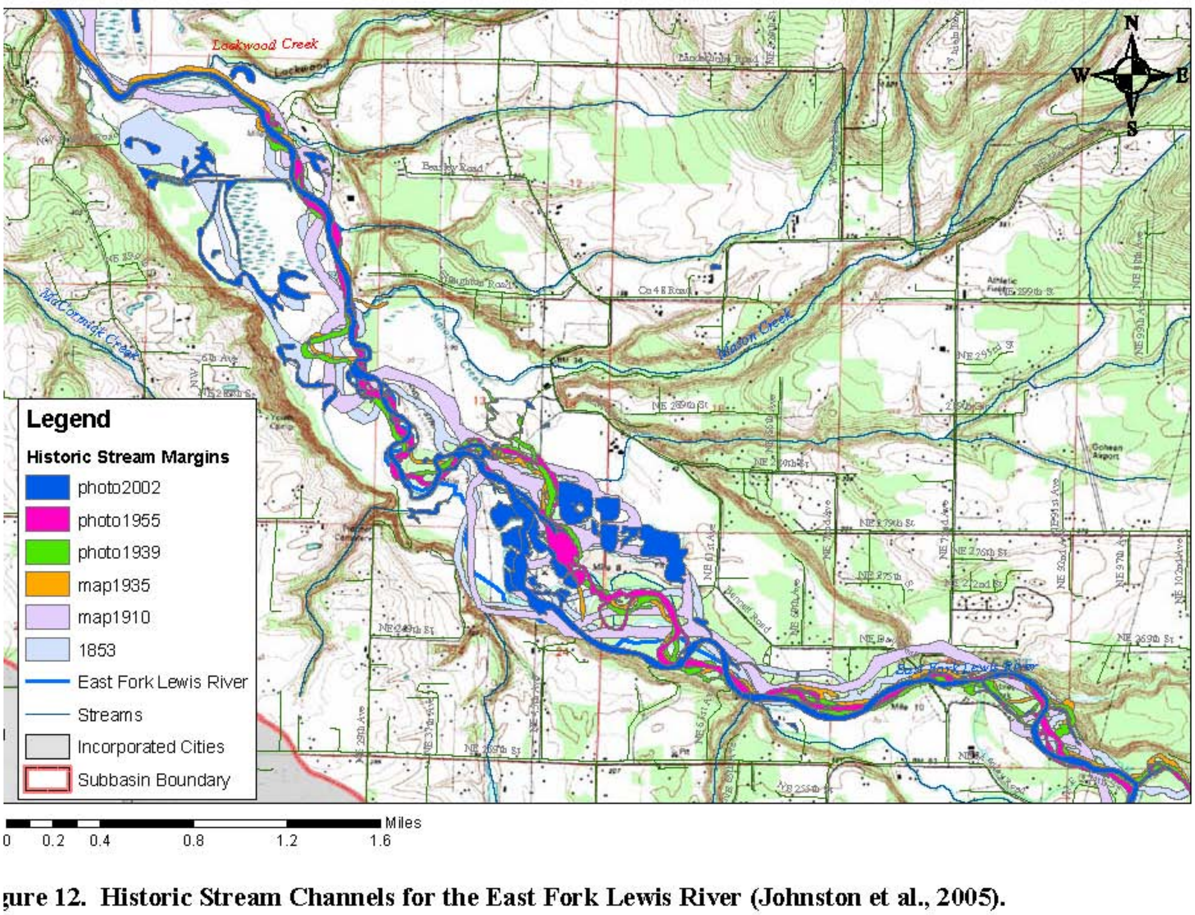


Miles

0 0.2 0.4 0.8 1.2 1.6

Figure 12. Historic Stream Channels for the East Fork Lewis River (Johnston et al., 2005).

Bank stability is a major concern along certain reaches of the lower 14 miles of the river. In this area soils and channel materials consist mainly of silts and sands, and lateral migration of the channel is common. Table 6 summarizes average channel migration by river mile. Unstable banks are counter-productive to riparian revegetation projects and result in lost time and money spent on the plantings (Figure 13).

The migration (avulsion) of the East Fork Lewis River into the gravel pits near RM 9 and the Ridgefield Pits (RM 8) in the mid-1990s caused significant changes in bank and channel stability in the area and in sediment supply both upstream and downstream of the avulsions (Wade, 2000). The avulsion of the East Fork into the Ridgefield pits is shown in Figure 14.

Figure 13. Revegetation project that is being eroded away near river mile 6.5. Photo taken 8 March 2005.

The TMDL technical study will not evaluate hydromodifications or enhancement projects. However, bank/channel enhancements and implementation measures that reduce width/depth ratios will reduce heating impacts in a reach that is too wide and shallow and/or will protect riparian revegetation projects from being washed away by an aggrading stream channel.

Table 6. Channel Migration Rates in the East Fork Lewis River. Table adapted from Wade (2000).

Location	Type of Migration	Average Migration (ft/year)
RM 10 – RM 9.3	Lateral (side to side)	6
	Longitudinal (Up/Down Valley)	36
RM 9.3 – RM 9	Lateral (side to side)	6
	Longitudinal (Up/Down Valley)	9
RM 9	Lateral (side to side)	5 and 100*
	Longitudinal (Up/Down Valley)	-
RM 9 – RM 8	Lateral (side to side)	30
	Longitudinal (Up/Down Valley)	27
RM 8 – RM 7.5	Lateral (side to side)	-
	Longitudinal (Up/Down Valley)	42
RM 7.5 – RM 7	Lateral (side to side)	25
	Longitudinal (Up/Down Valley)	25

* Short-term channel migration between 1996 and 1998

Figure 14. Aerial photo of Ridgefield Pits on the East Fork Lewis River. Photo adapted from Wade (2000).

Climate

The climate of the East Fork Lewis River subbasin is moderated by its proximity to the Pacific Ocean to the west and the Cascade Mountains directly to the east. The headwaters of the East Fork receive between 100 to 120 inches of precipitation yearly. The lower valley near the mouth receives between 40 to 50 inches of precipitation per year, approximately half the precipitation received at the headwaters (Figure 15).

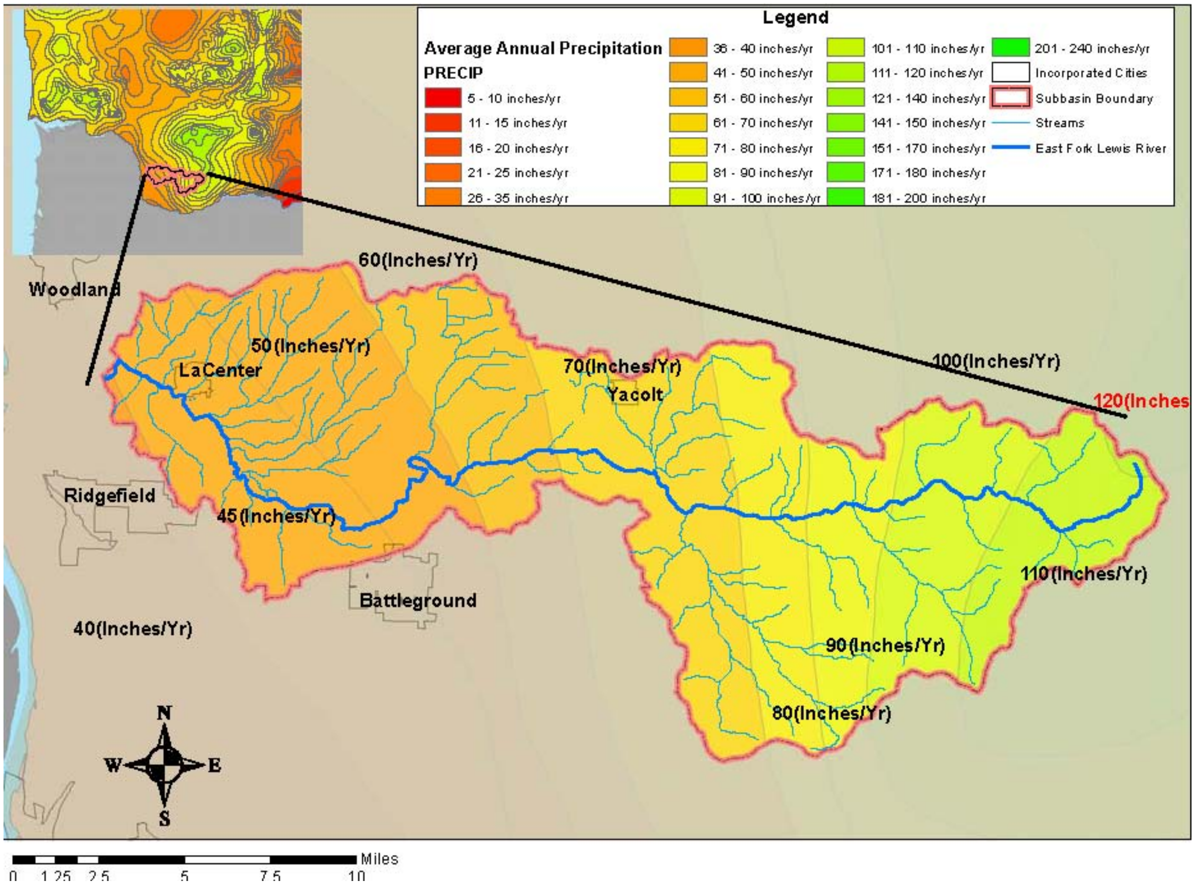


Figure 15. Average Annual Precipitation Map for the East Fork Lewis River Subbasin.

Much of the precipitation that falls in the upper part of the subbasin occurs as snow during the winter and rain on snow during the late winter through spring (Figure 16). The consensus of climatologists in Washington State predict one of the effects of global climate change in the Pacific Northwest will be increased average annual air temperatures and reduced snow pack levels at higher elevations. The result will be less water storage as snow in the winter, more precipitation contributing to streamflow during the winter, and lower baseflows in the summer (Storck, 2004; Miles, 2004; Hamlet, 2004). Gradual rises in average winter air temperatures contribute to the rise in snow elevation levels and temporal changes in the basin hydrograph. Increases in average summer air temperatures contribute to higher than average instream temperatures caused by conduction of heat at the air-water interface.

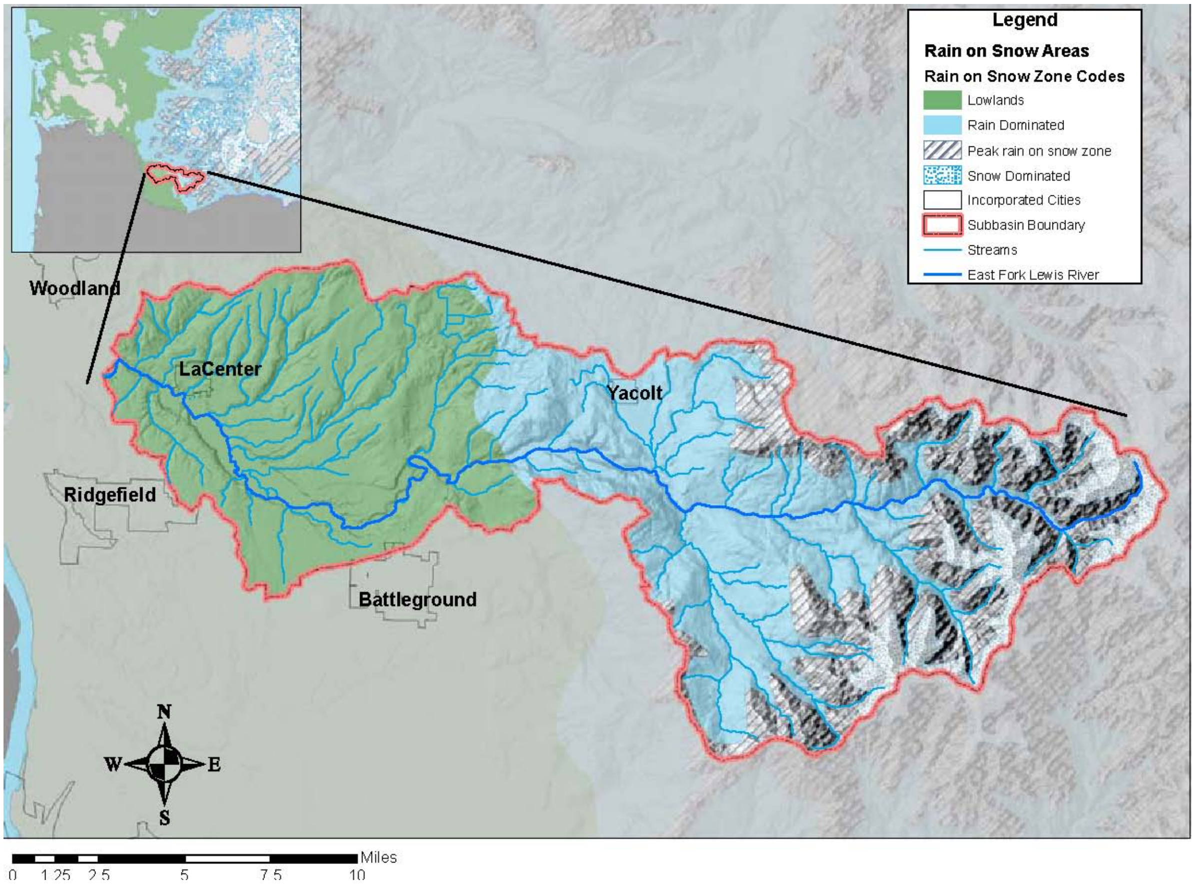
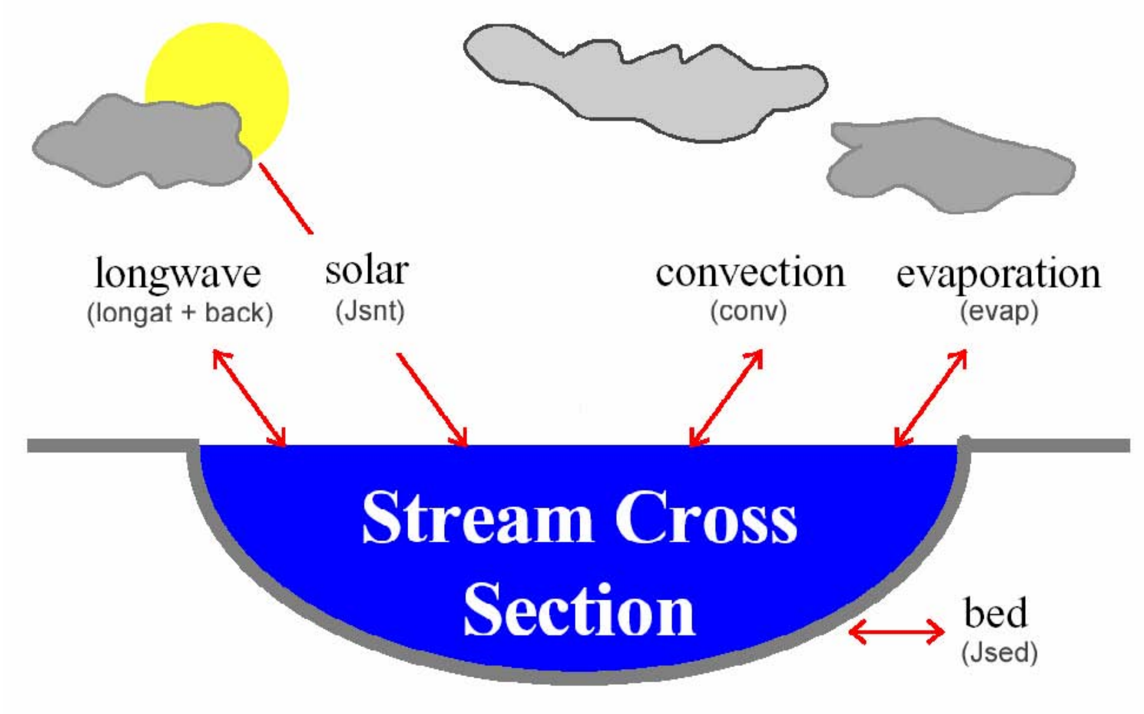


Figure 16. Areas of Rain and Snow Dominance in the East Fork Lewis Subbasin (WADNR Forest Practices Division, 1991).

Nonpoint Sources

Temperature

The East Fork Lewis River temperature TMDL will be developed for heat (i.e., incoming solar radiation). Heat is considered a pollutant under Section 502(6) of the Clean Water Act. The transport and fate of heat in natural waters has been the subject of extensive study. Edinger et al. (1974) provide an excellent and comprehensive report of this research. Thomann and Mueller (1987) and Chapra (1997) have summarized the fundamental approach to the analysis of heat budgets and temperature in natural waters that will be used in this TMDL. Figure 17 shows the major heat energy processes or fluxes across the water surface or stream bed.



Adams and Sullivan (1989) reported that the following environmental variables are the most important drivers of water temperature in forested streams:

Stream depth. Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.

Air temperature. Daily average stream temperatures are strongly influenced by daily average air temperatures. When the sun is not shining, the water temperature in a volume of water tends toward the dewpoint temperature (Edinger et al., 1974).

Solar radiation and riparian vegetation. The daily *maximum* temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily *average* temperatures are less affected by removal of riparian vegetation.

- **Groundwater**. Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream and the difference in temperatures between the groundwater and the stream.

The heat exchange processes with the greatest magnitude are as follows (Edinger et al., 1974):

Shortwave solar radiation. Shortwave solar radiation is the radiant energy that passes directly from the sun to the earth. Shortwave solar radiation is contained in a wavelength range between 0.14 µm and about 4 µm. The peak values during daylight hours are typically about three times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.

Longwave atmospheric radiation. The longwave radiation from the atmosphere ranges in wavelength from about 4 µm to 120 µm. Longwave atmospheric radiation depends primarily on air temperature and humidity and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes.

Longwave back radiation from the water to the atmosphere. Water sends heat energy back to the atmosphere in the form of longwave radiation in wavelengths ranging from about 4 µm to 120 µm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from longwave back radiation typically ranges from about 300 to 500 W/m^2.

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation are well documented (for example Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982; Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al. (1992); Beschta et al. (1987); Bolton and Monahan (2001); Castelle and Johnson (2000); CH2MHill (2000); GEI (2002); Ice (2001); and Wenger (1999). All of these summaries of the scientific literature indicate that riparian vegetation plays an important role in controlling stream temperature. The important benefits that riparian vegetation has upon the stream temperature include:

Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.

Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.

Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land cover type and condition by affecting floodplain and instream roughness, contributing coarse woody debris and influencing sedimentation, stream substrate composition, and stream bank stability.

Rates of heating to the stream surface can be dramatically reduced when high levels of shade are produced and heat flux from solar radiation is minimized. There is a natural maximum level of shade that a given stream is capable of attaining, which is a function of species composition, soils, climate, and stream morphology.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Mass transfer processes refer to the downstream transport and mixing of water throughout a stream system and inflows of surface water and groundwater. The downstream transport of dissolved/suspended substances and heat associated with flowing water is called advection. Dispersion results from turbulent diffusion that mixes the water column. Due to dispersion, flowing water is usually well mixed vertically. Stream water mixing with inflows from surface tributaries and subsurface groundwater sources also redistributes heat within the stream system. These processes (advection, dispersion, and mixing of surface and subsurface waters) redistribute the heat of a stream system via mass transfer. Turbulent diffusion can be calculated as a function of stream dimensions, channel roughness, and average flow velocity. Dispersion occurs in both the upstream and downstream directions. Tributaries and groundwater inflows can change the temperature of a stream segment when the inflow temperature is different from the receiving water.

Bacteria

The water quality standards use fecal coliform bacteria as indicators of pathogenic organisms associated with fecal contamination. Fecal coliform bacteria are produced in the gut of warm-blooded mammals and are present in high concentrations in fecal material. Potential sources of fecal coliform bacteria include humans, domestic animals, and wildlife. Fecal contamination of water is of concern as a human public health threat via incidental ingestion during recreation as well as via direct consumption.

Humans may contribute to nonpoint source fecal contamination via improperly maintained, poorly located, or failing septic systems. Properly functioning septic systems allow solids to settle to the bottom of a tank where they are partially decomposed. If solids accumulate and the tank is not pumped on a regular basis, the settling capacity of the tank is reduced and solids may flow out of the tank with the effluent. In a conventional septic system, the septic tank effluent flows to a drainfield, which is a network of perforated pipes set in gravel-filled trenches. Final treatment of the sewage effluent occurs through biological activity and physical filtration within the gravel trenches and in the unsaturated soil beneath the drainfield. Inadequate inspection and maintenance of a septic system, over use, and physical disturbance represent a few factors that can contribute to system failure. When a system fails, the treatment process is incomplete and nutrients, bacteria, and other contaminants in sewage can reach groundwater, streams, or lakes.

Human waste can also reach streams directly or indirectly through leaking sewer systems and from recreational users. Leaks in sewer systems occur as the infrastructure ages and as surrounding soils are disturbed by construction or by tree roots. Recreational users may contribute nutrients and bacteria due to improper waste disposal practices.

Domestic animals, such as dogs and cats, contribute to fecal coliform bacterial contamination when owners fail to clean up and properly dispose of pet waste. Stormwater runoff may transport fecal matter to the stormwater infrastructure or directly to surface water features. Domestic animals such as horses, cows, and sheep may contribute via overland flow during storms, unmanaged animal access, or from improper manure storage and disposal.

Birds and other wildlife may contribute directly to waterbodies or indirectly via overland stormwater runoff. Unless wildlife populations have increased due to anthropogenic activities, wildlife contributions are considered natural background conditions which may be quantified in the TMDL study but would not be expected to be reduced.

Point Sources

Various point sources discharge to the East Fork Lewis River under NPDES permits. These include both individual and general permits, which are listed in Table 7. There are three municipal wastewater treatment facilities located in the East Fork Lewis River basin. Wastewater treatment plants contribute treated wastewater which may contain fecal coliform bacteria, a parameter of concern in the East Fork Lewis River. Monthly fecal coliform data submitted by Paradise Point State Park since January 2003, as part of NPDES permit requirements, indicate that the facility violated their fecal coliform permit limit on December 1, 2003. The facility failed to report fecal coliform data on two occasions since January 2003. Paradise Point State Park is currently adding a drain field to the facility to eliminate the direct discharge to the East Fork Lewis River. Fecal coliform data from the LaCenter Sewage Treatment Plant indicates that the facility has had no violations since 1999. Prior to 1999, the facility reported 7 violations between 1995 and 1999. Fecal coliform data from the Larch Correction Center shows the facility violated fecal coliform Class AA criteria on four occasions between 1995 and 1997; however, the facility has had no violations since 1998.

Table 7. Permitted Surface Water Discharges to East Fork Lewis River

Facility	Permit Number	Type of Discharge	Relevant Parameters
		Individual Permits	
LaCenter Sewage Treatment Plant	WA0023230C	Municipal wastewater	fecal coliform and temperature
Paradise Point State Park	WA0037184A	Municipal wastewater	fecal coliform and temperature
Larch Correction Center	WA0038687A	Municipal wastewater	fecal coliform and temperature
Phase I Stormwater Permit (Clark Co.)	WA- 004211-1	Municipal Separate Storm Sewer Systems	fecal coliform and temperature
WSDOT Statewide Permit (12 outfalls)		Municipal Separate Storm Sewer Systems	fecal coliform and temperature
		General Permits	
Sand and Gravel (4)		Sand and gravel operations process and stormwater	temperature
Dairy (3)		All dairy process water and stormwater	fecal coliform
Stormwater/ Construction (3)		Construction site stormwater	temperature

Effluent from the wastewater treatment plants may also contribute heat loads to the receiving waterbody. None of the wastewater treatment permits within the East Fork Lewis River basin establish permit limits on effluent discharge temperature. However, the Larch Correction Center reported monthly effluent temperature data. The data show violations of the Class AA criterion during the summer months (June – September) in 1999 through 2004. The LaCenter Sewage Treatment Plant and Paradise Point State Park do not have effluent temperature data available for analysis.

Clark County has an individual municipal stormwater NPDES phase I permit. The permit coverage includes all areas within unincorporated Clark County, served by or otherwise contributing to discharges from municipal separate storm sewers owned or operated by Clark County to surface or ground waters of the State of Washington. As required by §402(p)(3) of the Clean Water Act, discharges covered under the permit must effectively prohibit non-stormwater discharges into storm sewers, and must apply controls to reduce the discharge of pollutants to Waters of the U.S. to the maximum extent practicable (MEP). The municipal stormwater NPDES permit requires the on-going development and implementation of a stormwater management program for municipal separate storm sewers owned or operated by the permittee. Section 6 of the permit includes a provision related to TMDLs that states "…When controls for stormwater discharges are necessary to implement a TMDL, stormwater management programs must be modified appropriately."

Washington Department of Transportation (WSDOT) has a statewide NPDES permit for all areas covered by Phase I and Phase II of the municipal stormwater permit program. There are 12 WSDOT stormwater outfalls covered under the state wide permit within the East Fork Lewis River basin. The permit is currently undergoing revisions and is scheduled for issuance in March 2006. The current permit does not include specific provisions relating to a TMDL, but the stormwater regulations require WSDOT to develop, implement, and enforce a stormwater management program (SWMP). The SWMP (originally published in 1997) describes the procedures and practices WSDOT uses to reduce the discharge of pollutants from their stormwater system to the maximum extent practicable (MEP) to protect water quality.

Four facilities operate under the Sand and Gravel General Permit, which was recently revised and reissued in January 2005. The old permit did not have temperature limitations for permittees; therefore, only one facility submitted temperature data. All of the temperature data available for J L Storedahl & Sons Daybreak Pit, which collected an instantaneous temperature measurement once per summer starting in July 2002, indicates that the facility violates their new permit limit (Class A temperature criteria) at the point of measurement. The owners of J L Storedahl & Sons Daybreak Pit have developed a Habitat Conservation Plan (HCP) for the property. The HCP should correct the temperature problems associated with the ponds on the property and these management measures will be analyzed as part of the TMDL (R2 Resource Consultants, 2000).

Three facilities operate under the Dairy Operations General Permit. The Department of Ecology administers the general permit to cover dairy operations. On July 1, 2003, jurisdiction for the dairy waste program was transferred to the Washington State Department of Agriculture (WSDA) under the Livestock Nutrient Management Program. However, until EPA delegates permit authority to WSDA, Ecology will continue to administer the permit, with inspections performed by WSDA. The current general permit does not include specific provisions relating to a TMDL, but dairies are not allowed to discharge dairy waste to surface waterbodies except under catastrophic conditions. Waste storage facilities must be "… designed, constructed, and operated to treat all process-generated wastewater plus the runoff from a 25-year 24-hour rainfall event…."

Currently, three facilities have stormwater construction permits through a general permit. Sites must follow the requirements of the general permit, and no site-specific information is included.

No provision for discharges to impaired waters is included, but section S5 states that the "…permittee is responsible for achieving compliance with state of Washington surface water quality standards…."

Study Design

The TMDL technical assessment for the East Fork Lewis River will use riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream will be calculated in the TMDL in a heat budget that accounts for surface heat flux and mass transfer processes. Heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade will be used as a surrogate to thermal load as allowed under EPA regulations (defined as "other appropriate measure" in 40 CFR §130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Other factors influencing the distribution of the solar heat load also will be assessed, including increases in the width of stream channels.

The *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program* (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional 'pollutant,' the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not."

Temperature Technical Study

Field data collection for development of the temperature TMDL consists of five different study components:

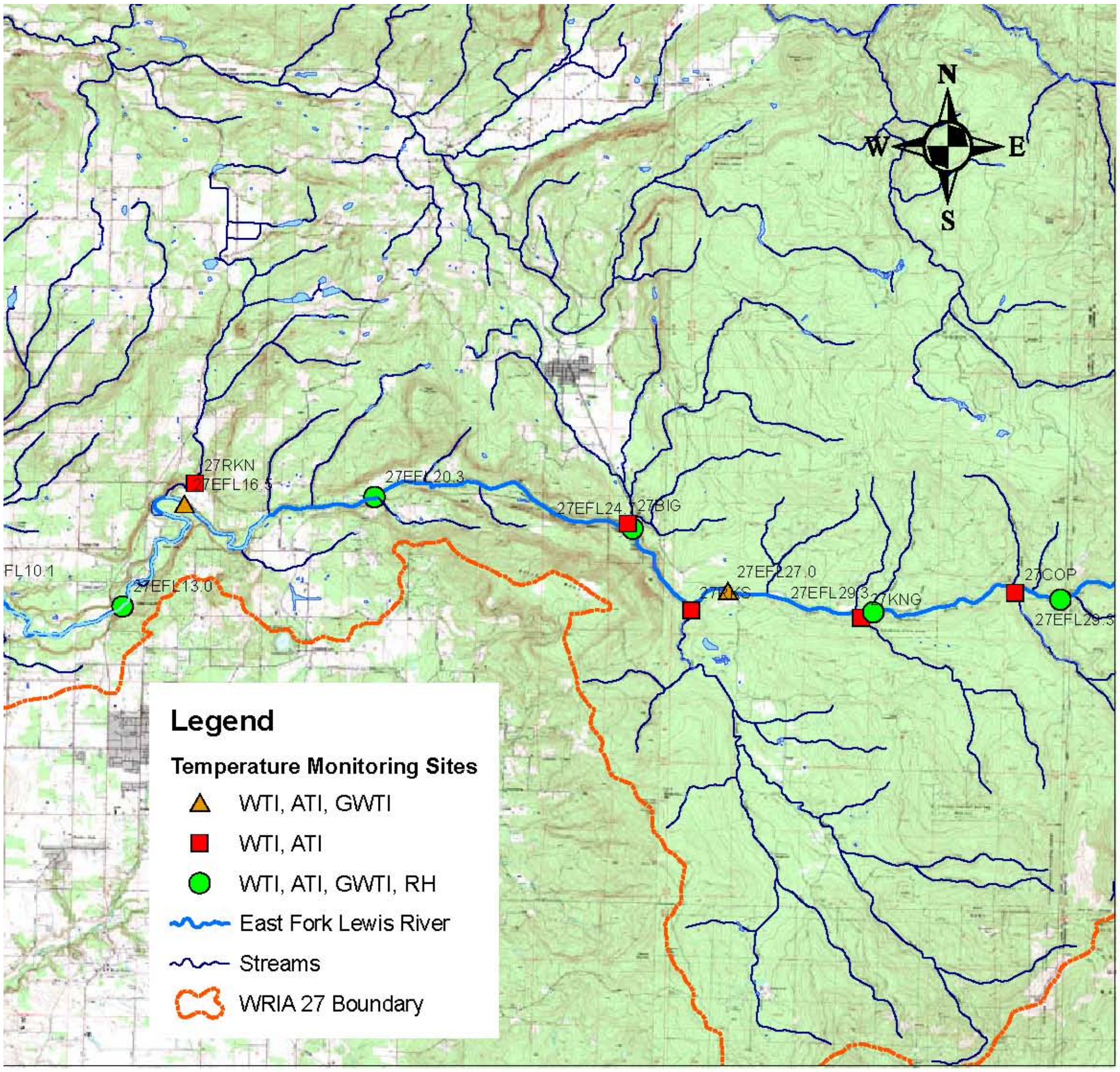
continuous temperature monitoring,
streamflow measurements,
groundwater monitoring using piezometers within the mainstem,
channel geometry surveys, and
riparian habitat surveys.

Ecology plans to use data collected by third parties to supplement the channel geometry and riparian habitat surveys. The proposed monitoring stations and associated measurement parameters are listed in Table 8 and shown in Figure 18.

Temperature Component

Continuous temperature monitoring stations will consist of both instream and air temperature thermistors co-located to characterize the average instream temperature and air temperatures near the station. Site selection and installation protocols will follow standard Ecology procedures developed for temperature TMDLs (Bilhimer and Lemoine, 2004). Thermistors will be programmed to record measurements at 30-minute sample intervals. The thermistors used for instream temperatures have an accuracy of ±0.2°C, air temperature thermistors have an accuracy of ±0.4°C.

Instream thermistors will be placed in the stream thalweg (line of deepest water in a stream channel normally associated with the zone of greatest velocity in the stream) at a depth in the middle of the water column to minimize the potential for vandalism or damage to boats or individuals recreating in the river. Thermistor placement away from the streambank will reduce measurement bias from cool groundwater temperatures in gaining reaches and placement within the main channel of streamflow to avoid measurement bias from the warmer stream edges and from thermal stratification in pools. Stream temperature measurements both longitudinally along the stream and vertically as a temperature profile (for tidally influenced sites) will be made to assure thermistor placement in a well-mixed area.



itoring Sites. WTI = instream thermistor, ATI = air thermistor, GWTI = piezometer thermistor, RH = relative

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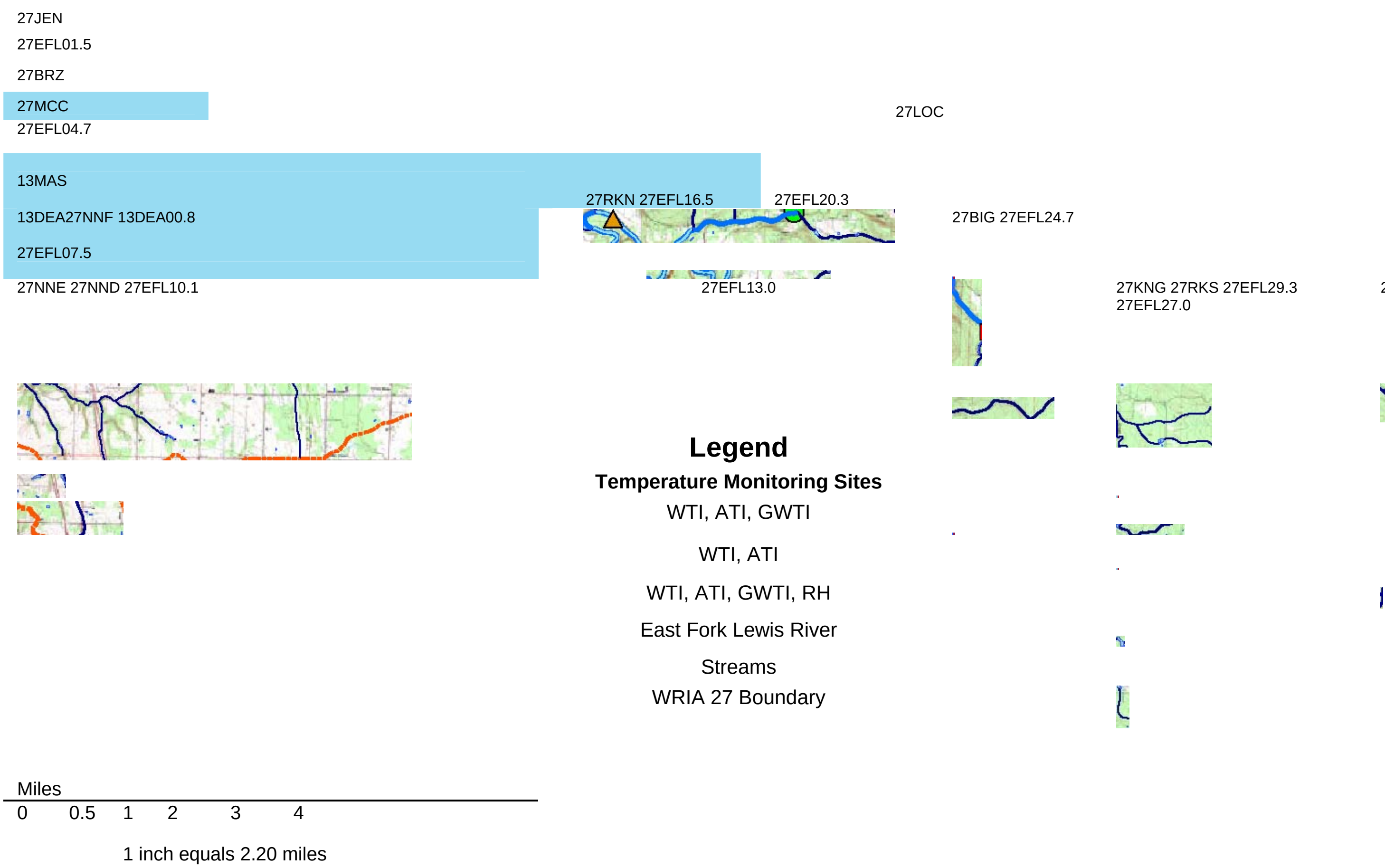


Table 8: Temperature monitoring stations

Station Id	Station Description	RM	Instream Temp.	Air Temp.	Piezometer	Relative Humidity
27EFL01.9	EF Lewis near 24th Ave	1.9	x	x	x	x
27EFL04.7	EF Lewis nr Landerholm Rd	4.7	x	x	x	
27EFL07.5	EF Lewis nr gravel pits	7.5	x	x	x	
27EFL10.1	EF Lewis at Ne 72nd Ave	10.1	x	x	x	
27EFL13.0	EF Lewis at Hwy 503	13.0	x	x	x	x
27EFL16.5	EF Lewis abv Rock Cr	16.5	x	x	x	
27EFL20.3	EF Lewis at USGS gauge	20.3	x	x	x	x
27EFL24.7	EF Lewis ds of Big Tree	24.7	x	x	x	x
27EFL27.0	EF Lewis at Dole Valley R	27.0	x	x	x	
27EFL29.3	EF Lewis at Co 12 Rd	29.3	x	x	x	x
27EFL32.5	EF Lewis abv Copper Cr	32.5	x	x	x	x
13DEA	Dean Creek near mouth	0.0	x	x		
13DEA00.8	Dean Cr at J.A. Moore Rd	0.8	x	x		
13MAS	Mason Cr at mouth	0.0	x	x		

27BIG	Big Tree @ Lucia Falls Rd	0.0	x	x		
27BRZ	Brezee Cr at ped bridge	0.0	x	x		
27COP	Copper Cr nr mouth	0.0	x	x		
27KNG	King Cr nr mouth	0.0	x	x		
27LOC	Lockwood Cr at Co 48 Rd	0.0	x	x		
27MCC	McCormick @ NW LaCenter	0.0	x	x		
27NND	NoName at NE Septon Dr	0.0	x	x		
27NNE	NoName nr 259th St	0.0	x	x		
27NNF	NoName at rm 7	0.0	x			
27RKN	Rock Cr at NE 319th St	0.0	x	x		
27RKS	Rock Cr nr mouth	0.0	x	x		

Groundwater Component

The purpose of the groundwater component of this study is to determine groundwater contributions and interactions throughout the study area. The groundwater flux and the associated heat transfer to the East Fork Lewis River will be examined by using mini-piezometers in the mainstem. Additionally, several observation wells that have already been installed will be used to determine the direction of groundwater flow near the piezometers transect.

Mini-piezometers are small diameter pipes (1½ inches) with openings at the bottom. They can be used to measure vertical hydraulic gradients between the East Fork Lewis River and the water-table as well as allow for sampling of limited water quality indicators. Mini-piezometers will be installed near 11 stations on the East Fork Lewis River (Figure 18 and Table 8). The piezometers will be hand driven into the stream bed to a depth of approximately 5 feet. The piezometers will be used to classify groundwater influences within the watershed.

Water levels in the piezometers will be measured monthly between May and October 2005 using a calibrated electric well probe or steel tape in accordance with standard USGS methodology (Stallman, 1983). The head difference between the internal piezometer water level and the external creek stage provides an indication of the vertical hydraulic gradient and the direction of flow between the creek and groundwater. When the piezometer head exceeds the creek stage, groundwater discharge into the creek can be inferred. Similarly, when creek stage exceeds the head in the piezometer, loss of water from the creek to groundwater storage can be inferred.

The piezometers will also be instrumented with 2-3 continuously recording thermistors, placed at different depths based on a thermal profile measured at the time of installation, to determine the temperature of the groundwater within the hyporheic zone. In order to define the influence of tidal exchanges in the lower 6.5 miles of the East Fork, a continuously recording pressure transducer will measure stage height changes in piezometers in this reach. This data will provide a clearer picture of the diurnal effect of tidal variations on the groundwater condition at the piezometers.

Riparian Habitat and Channel Geometry Components

The riparian habitat field data collected and compiled as part of the East Fork Lewis River

Basin Habitat Assessment includes a GIS map of riparian vegetation in a 100ft buffer around the East Fork Lewis River and several tributaries (Johnston et al., 2005). The map layer includes data on vegetation type, general height class, and vegetation density. Vegetation heights will be measured in the field using a laser range/height finder if necessary. Hemispherical photography and channel surveys will follow protocols defined in the Draft Temperature TMDL Field Measurement Protocols (Bilhimer and Lemoine, 2004).

Image analysis of digital hemispherical pictures and field measurements taken using a Solar Pathfinder at the center of the stream will be used to estimate the total solar radiation contribution at the stream surface at each temperature monitoring station during the critical period. This data will provide validation for the site factor assumptions and effective shade predictions generated from the SHADE model.

Stream channel geometry data in the lower valley has been collected by Friends of the East Fork Lewis River (Dover Habitat Restoration LLC, 2003) and the Lower Columbia Fish Recovery Board (Johnston et al., 2005). Channel geometry measurements in the lower valley are subject to extreme changes due to a high rate of channel migration and aggradation. The usefulness of transect data from outside parties will be evaluated during the field study and additional transects identified as significantly changed will be surveyed again.

Streamflow Studies

Both parts of this TMDL, temperature and bacteria, require streamflow measurements to accurately represent pollutant loading and to understand how water moves within the system. Streamflow measurements and time-of-travel studies for this TMDL will not be used to set instream flows, but the data collected can help inform those regulatory processes.

The USGS has operated a streamflow gauge on the East Fork Lewis River near Heisson Road since 1929, and this station will be included in the streamflow network. Ecology has added a telemetry streamflow gauge on the mainstem at Daybreak Park (river mile 10.1) as part of its statewide streamflow monitoring network. This station will also record measurements of instream temperature (from the pressure transducer) and air temperature at the gauge housing every 15 minutes. Past comparisons of instream temperature readings by similar streamflow gauges with a paired instream thermistor show small temperature differences between the instruments (typically less than ±0.5°C).

Two additional streamflow gauges will be installed and maintained by Ecology on the mainstem East Fork Lewis River for the duration of the TMDL technical study. The first gauge will be installed at the Interstate 5 crossing (river mile 1.9) and the second near the Gifford Pinchot National Forest boundary (river mile 32.5). The gauges will be used to characterize the streamflow at the study area boundaries. Data from the Daybreak Park stream gauge and the Interstate 5 gauge will be compared to characterize the tidal bulge influence from the Columbia River. Vertical conductivity and temperature gradients will be measured during site visits to the lower reaches of the East Fork to determine the depths of the water moving up from the Columbia River.

Seepage runs conducted during baseflow conditions and the resulting flow mass balance will be used to determine both the tributary discharge to the East Fork Lewis River and streamflow lost or gained to groundwater. All surface water inputs that will be measured are listed in Table 9 as flow measurements. Several of the tributaries are gauged by third parties and Ecology will perform discharge measurements at these locations to compare to established discharge rating curves. Table 9 provides a list of the locations that streamflow will be measured throughout the basin. Several unwadeable locations will be measured using Acoustic Doppler Current Profiler (ADCP) technology by Ecology Stream Hydrology Unit staff.

Table 9. Streamflow Measurement Stations for Temperature and Bacteria Studies

Station Id	Station Description	RM	Stream Type	Stream Gauge	Flow Meas.	Gauge Mngr	ADCP
27EFL01.9	EF Lewis near 24th Ave	1.9	mainstem	x	x	SHU	x
27EFL04.7	EF Lewis near Landerholm Rd	4.7	mainstem		x		x
27EFL07.5	EF Lewis near gravel pits	7.5	mainstem		x		x
27EFL10.1	EF Lewis at NE 72nd Ave	10.1	mainstem	x	x	SHU	
27EFL13.0	EF Lewis at Hwy 503	13.0	mainstem		x		
27EFL16.5	EF Lewis above Rock Cr	16.5	mainstem		x		
27EFL20.2	EF Lewis at Heisson USGS gauge	20.2	mainstem		USGS		
27EFL20.3	EF Lewis at USGS gauge	20.3	mainstem	x		USGS	
27EFL24.6	EF Lewis above Big Tree Cr	24.6	mainstem		x		
27EFL27.0	EF Lewis at Dole Valley R	27.0	mainstem		x		
27EFL29.3	EF Lewis at Co 12 Rd	29.3	mainstem		x		
27EFL32.5	EF Lewis above Copper Cr	32.5	mainstem	x	x	SHU	x
27EFL3.15	EF Lewis off Lacenter Rd	3.15	mainstem		x		
27BRZSW1	Stormwater Culvert near Cedar and 4th	0.25	storm drain		x		
13DEA	Dean Creek near mouth	0.0	tributary		x		
13DEA00.8	Dean Cr at J.A. Moore Rd	0.8	tributary		x		
13MAS	Mason Cr at mouth	0.0	tributary		x		
27ANA	Anaconda Cr at Co 12 Rd	0.0	tributary		x		
27BAS	Basket Creek at Flat Rd	0.0	tributary		x		
27BIG	Big Tree @ Lucia Falls Rd	0.0	tributary		x		
27BRZ	Brezee Cr at pedestiran bridge	0.0	tributary		x		
27BRZ0.5	Brezee Creek off 4th near Stonecreek	0.5	tributary		x		
27COP	Copper Cr near mouth	0.0	tributary		x		
27JEN	Jenny Cr at Pacific Hwy	0.0	tributary		x		
27KNG	King Cr near mouth	0.0	tributary		x		
27LOC	Lockwood Cr at Lockwood Cr Rd	0.0	tributary		x		
27LOC0.1	Lockwood Creek off NE John Storm Ave	0.1	tributary		x		
27LOC3.15	Lockwood Cr off Lester Ave	3.15	tributary		x		
27MAS1.23	Mason Cr at Moore Rd	1.23	tributary		x		
27MAS3.19	Mason Cr at JR Anderson Rd	3.19	tributary		x		
27MAS4.57	Mason Cr at 102nd Ave NE	4.57	tributary		x		
27MCC	McCormick @ NW laCenter	0.0	tributary		x		

27MCC2.0	McCormick Cr at NW Spencer Rd	2	tributary		x		
27MCC3.4	McCormick Cr at NE 289th and Timmen Rd	3.4	tributary		x		
27NIC	Niccolls Cr at Co12 Rd	0.0	tributary		x		
27NNA – 27NNL	12 unnamed tribs entering mainstem between Old Pac Hwy and Clearwater Dr	0.0	tributary		x		
27RCN0.65	Rock Cr N at Hammond Rd	0.65	tributary		x		
27RCN2.8	Rock Cr N at NE Gabriel Rd	2.8	tributary		x		
27RCS3.9	Rock Cr S at Dole Valley Rd	3.9	tributary		x		
27REI	Reinhardt Cr at Co 12 Rd	0.0	tributary		x		
27RIL0.95	Riley Creek off Johnson Rd	0.95	tributary		x		
27RKN	Rock Cr at NE 319th St	0.0	tributary		x		
27RKS	Rock Cr near mouth	0.0	tributary		x		
27ROG	Roger Cr at Co 12 Rd	0.0	tributary		x		
27YAC0.90	Yacolt Cr at Railroad Ave	0.9	tributary		x		
27YAC3.60	Yacolt Cr at Chilcote Dr	3.6	tributary		x		

A time of travel study will be conducted on the East Fork Lewis River using rhodamine dye during baseflow conditions. The dye is non-toxic and biodegradeable and only visible near the point of injection. Estimates of travel time will be calculated using the arrival time of the peak concentration of dye at the downstream station, instream flow measurements, length of stream reach, and the dye concentration profile over time. Dispersion will be calculated from the spread of the plume as it is advected downstream. The time of travel study will allow determination of the reach-average velocity between monitoring stations.

Fecal Coliform Bacteria

The project objectives will be met through characterizing annual and seasonal fecal coliform bacteria loads in the East Fork Lewis River. Sixteen months of fecal coliform and flow data will be collected to calculate basic fecal coliform concentration and loading data in various reaches of the watershed. If additional requirements for characterizing stormwater or industrial discharges are requested by the Water Quality Program, a longer or more intensive design may be necessary.

The sampling design will utilize a fixed network of sites sampled twice monthly (Table 10 and Figure 19). The fixed network will emphasize receiving water quality in the E. Fork Lewis River by targeting tributaries as well as mainstem sites and by bracketing land uses. Monitoring work will be consistent through all months of the year. Sampling for each survey will be conducted in two days by one team from Ecology. Samples will be taken as grab samples from a single location for all tributary sites and from two locations at the mainstem sites. The mainstem will be sampled 1/3 of the stream width away from the left bank and right bank. The arithmetic mean of the two samples will be used to determine the fecal concentration for the site. Sampling will occur at the lowest tide possible for monitoring stations influenced by tides.

The project will sample during eight to ten storm events. A storm event will be defined as 0.3 inches of rainfall in the previous 24 hours. It is expected that the storm sample criteria will be met during the course of the sixteen months of bi-monthly fixed network sampling. However, to ensure that eight storm events are sampled, the project will be evaluated at the end of January

2006 to determine if a sufficient number of storm events are being obtained. If five storm events have not been sampled at this point, the project will start specifically targeting storm events in addition to the bi-monthly sampling. If eight storm events have not been obtained by September 2006, then targeted storm event sampling will continue into the wet season until the criteria is reached.

Instantaneous discharge measurements or gauge readings will be obtained at each site during each sampling event to determine flow. Flow measurements will be continuously recorded at four sites on the mainstem of the East Fork Lewis River. The Ecology EA Program Environmental Monitoring and Trends Section Stream Hydrology Unit (SHU) will establish and maintain three stations located at the mouth (RM 0.75), Daybreak Park (RM 10.2), and the Gifford Pinchot Forest Boundary (RM 32.5). The United States Geological Survey (USGS) will provide data from their gauge at Heisson near river mile 20.2.

Data from the fixed network will provide fecal coliform data sets to meet the following needs:

Provide an estimate of the geometric mean and 90^{th} percentile statistics of fecal coliform counts over the year and within seasons.

Provide reach-specific bacteria loads and concentrations to define areas of fecal coliform contributions. With accurate flow monitoring, fecal coliform loads diverted to other uses can be separated from fecal coliform load losses from die-off or settling. Tributary and source loads will also be quantified.

Help delineate any jurisdictional responsibilities for fecal coliform sources, and

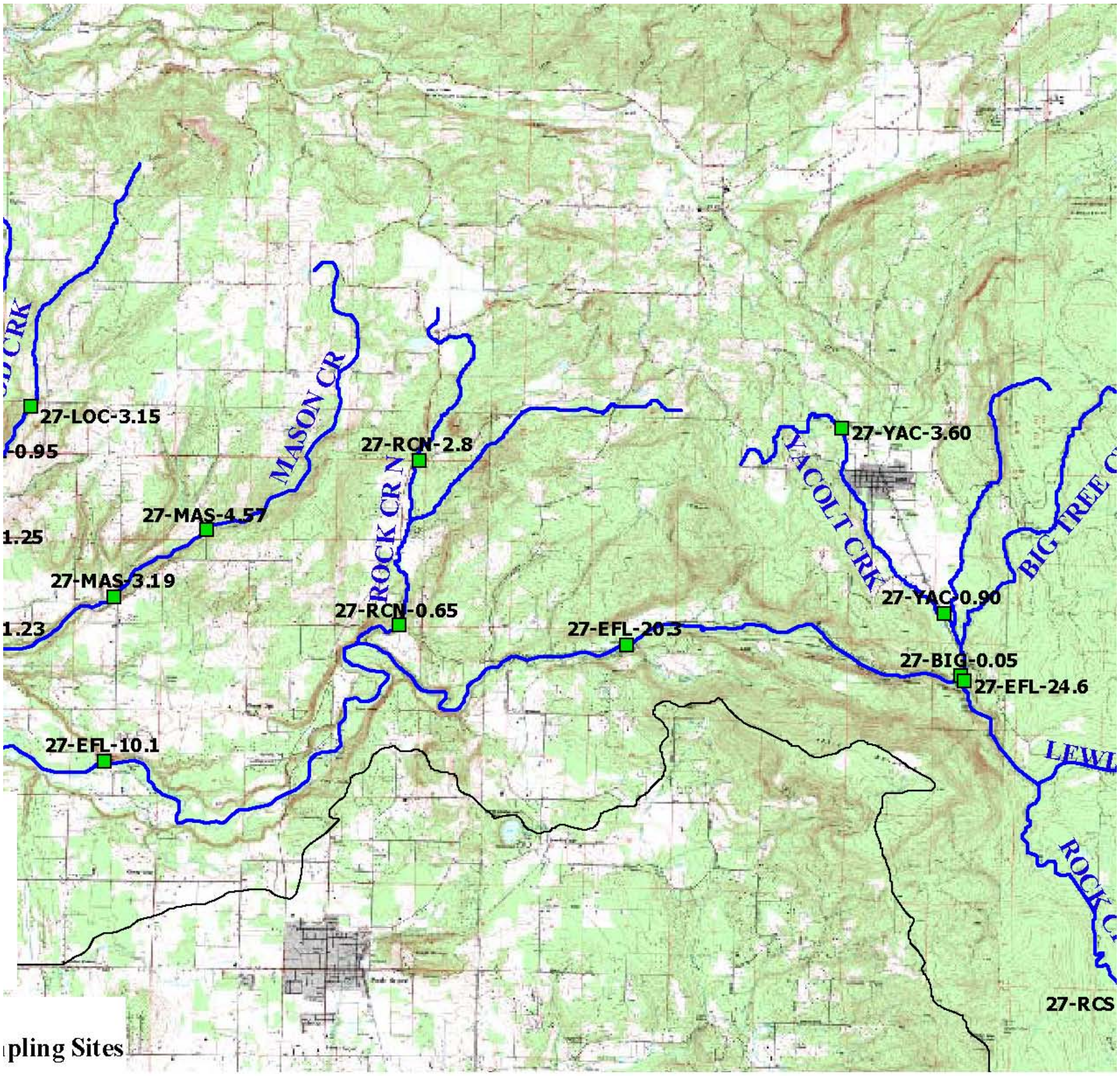
Determine the impact of various land uses on instream changes of fecal coliform concentrations.

The locations of the fixed-network water quality stations are listed in Table 10 and shown in Figure 19. Stations were selected to distinguish tributary from mainstem contributions and to distinguish among residential, agricultural, and recreational contributions within defined jurisdictions. Major tributaries and drains to each water body will be sampled as close to their confluence with the mainstem as possible. There are 28 sites: 5 sites on the mainstem of the East Fork Lewis, 21 tributary sites, two sites at the wastewater treatment plant (WWTP), and one stormwater culvert site. Arrangements will be made to split samples with the WWTP. Sites may be added or removed from the sampling plan depending upon preliminary results.

Table 10. Fecal coliform and Streamflow Monitoring Stations

Station ID	Site Description	RM	Stream Type	Fecal Coliform Measurement	Flow Measurement
27-EFL-0.75	EF Lewis under I-5 bridge	0.75	mainstem	X	SHU
27-JEN-0.35	Jenny Creek at Pacific Hwy crossing	0.35	tributary	X	X
27-MCC-1.18	McCormick Crk at LaCenter Rd	1.18	tributary	X	X
27-MCC-2.0	McCormick Crk at NW Spencer Rd	2	tributary	X	X
27-MCC-3.4	McCormick Crk at NE 289th and Timmen Rd	3.4	tributary	X	X
27-BRZSW-1	Stormwater Culvert near Cedar and 4th	0.25	storm drain	X	X
27-BRZ-0.07	Brezee Creek at mouth	0.07	tributary	X	X

27-BRZ-0.5	Brezee Creek off 4th near Stonecreek	0.5	tributary	X	X
27-EFL-3.15	EF Lewis off Lacenter Rd	3.15	mainstem	X	X
27-LOC-0.1	Lockwood Creek off NE John Storm Ave	0.1	tributary	X	X
27-LOC-1.25	Lockwood Creek off Lockwood Crk Rd	1.25	tributary	X	X
27-RIL-0.95	Riley Crk off Johnson Rd	0.95	tributary	X	X
27-LOC-3.15	Lockwood Crk off Lester Ave	3.15	tributary	X	X
27-MAS-0.25	Mason Creek near mouth	0.25	tributary	X	X
27-MAS-1.23	Mason Crk at Moore Rd	1.23	tributary	X	X
27-MAS-3.19	Mason Crk at JR Anderson Rd	3.19	tributary	X	X
27-MAS-4.57	Mason Crk at 102nd Ave NE	4.57	tributary	X	SHU
27-EFL-10.1	EF Lewis at Daybreak	10.2	mainstem	X	X
27-RCN-0.65	Rock Crk N at Hammond Rd	0.65	tributary	X	X
27-RCN-2.8	Rock Crk N at NE Gabriel Rd	2.8	tributary	X	USGS
27-EFL-20.3	EF Lewis at Heisson USGS gauge	20.2	mainstem	X	X
27-BIG-0.05	Big Tree Creek at Lucia Falls Rd	0.05	tributary	X	X
27-YAC-0.90	Yacolt Crk at Railroad Ave	0.9	mainstem	X	X
27-YAC-3.60	Yacolt Crk at Chilcote Dr	3.6	tributary	X	X
27-RCS-3.9	Rock Crk S at Dole Valley Rd	3.9	tributary	X	X
27-EFL-24.6	EF Lewis above Big Tree Crk	24.6	mainstem	X	SHU
27-STP-0.0	LaCenter Sewage Tratement Plant Effluent	-	effluent	X	X



ıpling Sites

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Laboratory Budget

Table 11 outlines the laboratory budget anticipated to complete the fecal coliform analyses for samples collected during this TMDL.

Table 11. Laboratory Budget

Program	No. Stations	No. Events	Samples per event	Parameter	Unit Cost	Total Samples	Total Cost
Twice-monthly Sampling	35	42	1	FC MF	21	1470	$30,870
QA Sampling	9	42	1	FC MF	21	378	$7,938
Project Total							**$38,808**

[1] Costs include 50% Ecologydiscount for Manchester Environmental Laboratory.

Project Schedule

Table 12 lists the proposed schedule for data collection, analysis, modeling, and reporting throughout the project.

Table 12. Proposed Schedule for TMDL Activities

Document or Activity	Completion Date
Final QA Project Plan	May 2005
Monitoring Activities	May 2005 through September 2006
Analyses, Modeling, and Report Writing	December 2005 through January 2007
Draft Technical Report for Supervisor Review	January 2007
Draft Technical Report for Internal Review	February 2007
Draft Technical Report for External Review	March 2007
Final Technical Report	June 2007
Environmental Information Management data entry	March 2007

Project Organization

The roles and responsibilities of Ecology project staff are as follows:

Stephanie Brock, *Environmental Assessment Program Nonpoint Studies Unit, Project Manager*: Responsible for overall project management of the study, including study design. Responsible for development of TMDLs for fecal coliform and temperature, including model development and writing the technical report.

Dustin Bilhimer, *Environmental Assessment Program Nonpoint Studies Unit, Temperature Investigator:* Responsible for assisting with development of the temperature study, QA Project Plan, temperature field data collection and data entry to EIM, and writing sections of the technical report related to temperature data collection and data quality review.

Lawrence Sullivan, *Environmental Assessment Program Water Quality Studies Unit, Bacteria Investigator:* Responsible for assisting in development of the bacteria study, QA Project Plan, bacteria field data collection and data entry to EIM, and writing sections of the technical report related to bacteria data collection and data quality review.

Barb Carey, *Environmental Assessment Program Nonpoint Studies Unit, Hydrogeologist*: Provides hydrogeologic assistance with study design, including interpretation of historical geology and groundwater data in the basin, groundwater data collection, data analysis, and report writing.

Chuck Springer, *Environmental Assessment Program Stream Hydrology Unit, Hydrologist*: Responsible for deploying and maintaining continuous flow gauges and staff gauges. Responsible for producing records of hourly flow data at sites selected for the study.

Debby Sargeant, *Environmental Assessment Program Water Quality Studies Unit, Reviewer:* Provides expertise/guidance related to the bacteria study. Reviews the bacteria portions of QA Project Plan and TMDL report.

Karol Erickson, *Environmental Assessment Program Water Quality Studies Unit, Unit Supervisor*: Reviews the portions of the QA Project Plan and TMDL report related to bacteria.

Darrel Anderson, *Environmental Assessment Program Nonpoint Studies Unit, Unit Supervisor*: Reviews the temperature portions of the QA Project Plan and TMDL report.

Will Kendra, *Environmental Assessment Program Watershed Ecology Section, Section Manager*: Responsible for approval of the QA Project Plan and final TMDL report.

Stuart Magoon, *Environmental Assessment Program, Manchester Environmental Laboratory, Director*: Provides laboratory and staff resources, sample processing, analytical results, laboratory contract services, and QA/QC of data. Reviews sections of the QA Project Plan relating to laboratory analysis.

- **Cliff Kirchmer**, *Environmental Assessment Program, Quality Assurance Officer*: Reviews QA Project Plan and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of the project.

Dave Howard, *Water Quality Program Southwest Regional Office, TMDL Project Lead*: Acts as point of contact between Ecology technical study staff and interested parties and coordinates information exchange and meetings. Supports, reviews, and comments on QA Project Plan and technical report. Responsible for implementation planning and preparation of TMDL submittal document for EPA.

Kim McKee, *Water Quality Program Southwest Regional Office, Unit Supervisor,*: Responsible for approval of TMDL submittal to EPA.

Kelly Susewind, *Southwest Regional Office, Section Manager*: Responsible for approval of TMDL submittal to EPA.

Quality Objectives

Temperature

Accuracy of the thermograph data loggers will be maintained by a two-point comparison between the thermograph and a Certified Reference Thermometer. The Certified Reference Thermometer, manufactured by HB Instrument Co. (part number 61099-035, serial number 2L2087), is certified to meet ISO9000 standards and calibrated against National Institute of Standards and Technology traceable equipment.

Manufacturer specifications report an accuracy of ±0.2°C for the Onset StowAway TidBit (-5°C to +37°C) and the Hobo Pro-Temp thermistors. The Onset StowAway TidBit (-20°C to +50°C) has a reported accuracy of ±0.4°C. The tidbits with a -20°C to +50°C range are necessary to measure air temperature because of the potential range of minimum and maximum temperatures anticipated in the basin. Water temperatures are measured using the tidbits with a -5°C to +37°C range.

If the mean difference between the NIST-certified thermometer and the thermal data loggers differs by more than the manufacturer's specifications during the pre-study calibration, the thermal data logger will not be used during field work.

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, and seasonal variation of instream flow and temperatures in the subbasin. Extra thermistors will be taken in the field during site visits and surveys to minimize data loss due to damaged or lost equipment.

Fecal Coliform Bacteria

Fecal coliform quality objectives include determining compliance with water quality criteria and collecting and analyzing data at the appropriate spatial and temporal scale to characterize pollution in the watershed. The study design achieves this objective by establishing 25 sites that will be sampled every two weeks. An overview of the sampling plan/design was included in the Study Design section of this QA Project Plan. The measurement quality objectives, including precision, bias, and sensitivity, are provided in the Measurement Quality Objectives section of the QA Project Plan.

Sampling Procedures

Standard Ecology protocols will be used for sample collection, preservation, and shipping to the Manchester Environmental Laboratory (MEL) (WAS, 1993; MEL, 2003). Chain-of-custody signatures will be required during sample transport. EA Program field methods will be followed for the collection of flow measurements (WAS, 1993). Flow meter calibration will follow EA Program protocols (WAS, 1993) under manufacturer's instructions. The principal investigator will validate the data, assess the data for usability, and analyze the data. The results of data validation and data quality assessment will be documented. Calibration data, field measurement data, and other notes will be maintained on water resistant paper in field notebooks. All sampling sites will have unique identification numbers.

Grab samples will be collected using WAS protocols (Ecology, 1993). Duplicate fecal coliform samples will be collected in the field in a side-by-side manner for 20% of the samples collected during an individual survey. Samples will be collected in the thalweg and just under the surface. Grab samples will be collected directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in MEL (2003). An extra set of sample containers will be available should any of the bottles be lost or contaminated. Microbiological and analytical methods, sample containers, volumes, preservation, and hold time are listed in Table 13. Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection.

Table 13. Laboratory Measurement and Method

Parameter	Bottle	Preservative	Holding Time	Standard Method	Reporting Limit
Fecal Coliform	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours	SM MF 9222D	1 cfu/100 mL

SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition

Measurement Procedures

Field measurement protocols for the temperature portion of this TMDL follow protocols developed by Ecology (Bilhimer and Lemoine, 2004) and derived from TFW protocols for temperature (Schuett-Hames et al, 1999). All field measurement events will occur with at least two field personnel and will follow the safety requirements of Ecology.

Total variation for field sampling and analytical variation will be assessed by collecting duplicate samples. Bacteria samples tend to have a high percent Relative Standard Deviation (RSD) compared to other water quality analyses. Bacteria samples will be assessed by collecting duplicates for approximately 20% of samples in each survey. MEL routinely duplicates sample analyses in the laboratory to determine the precision of analytical methods. The difference between the field duplicates and the laboratory replicates is an estimate of the sample field variability.

All samples will be analyzed at MEL. The laboratory's microbiology procedures and quality control procedures are summarized in the MEL Lab Users Manual (MEL, 2003). MEL will follow standard quality control procedures (MEL, 2003). Field sampling and measurements will follow quality control protocols described in Ecology (1993).

Measurement Quality Objectives

Field studies are designed to generate data adequate to reliably estimate the temporal and spatial variability of that parameter. Sampling, laboratory analysis, and data evaluation steps have several sources of error that should be addressed by measurement quality objectives. Precision in laboratory measurements (measurement quality objectives) can be more easily controlled than field sampling variability. Precision needs to be as high as possible in the laboratory. Precision for bacteria field duplicates is expressed as the coefficient of variation (CV) and results should not exceed 50% CV. At levels close to the method detection limit (less than 50 cfu/100 mL), a % CV greater than 50% is acceptable. The % CV is calculated by dividing the standard deviation by the mean of the duplicate pairs and multiplying by 100. If any of these targets are not met, the associated results will be qualified and used with caution.

Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time. Finally, laboratory and field errors are further expanded by estimate errors in seasonal loading calculations and modeling estimates.

Table 14 summarizes the field and laboratory measurement quality objectives for reasonable decisions for the study. Stratified seasonal sampling and other sampling design features will be used to better evaluate critical conditions on which to develop TMDL targets for the parameters.

Table 14. Summary of measurement quality objectives and required reporting limits of laboratory and field parameters.

Measurement	Accuracy(% deviationfrom true value)	Precision (relative standard deviation, RSD)	Bias (% deviationfrom true value)	Required Reporting Limits
Field Measurements				
Velocity*	±2% of reading; 0.1 ft/s	±0.05 ft/s	N/A	0.05 ft/s
Temperature*	0.2°C	0.025°C	0.05°C	1°C to 40°C
Laboratory Analyses				
Fecal Coliform (MF)	N/A	N/A	N/A	1 cfu/100 mL

* As units of measurements, not percentages

Field Measurements

The Onset StowAway TidBits will be calibrated pre- and post-study in accordance with TFW Stream Temperature Survey protocols (Schuett-Hames et al., 1999a) to document instrument bias and performance at representative temperatures. A NIST-certified reference thermometer will be used for the calibration. At the completion of the monitoring, the raw data will be adjusted, based on the pre- and post-calibration results, if the temperature for the TidBit differes from the NIST-certified reference thermometer by more than the stated reported accuracy of the TidBit (i.e by more than ±0.2°C or ±0.4ºC). The mean difference of the pre- and post-calibration values from the NIST thermometer reading will be used for calculating the adjusted temperature. Variation for field sampling of instream temperatures will be addressed with a field check of the data loggers with a reference temperature measurement at all thermograph sites upon deployment, download events, and at TidBit removals at the end of the study period. Field sampling and measurements will follow quality control protocols described in the WAS protocol manual (WAS, 1993) and the TFW Stream Temperature Survey Manual (Schuett-Hames et al., 1999a).

Laboratory Analysis

The accuracy required for laboratory data to meet the measurement quality objectives should be attainable through the methods listed in Table 15. The MEL laboratory staff will consult the project manager if any changes in procedures over the course of the project are recommended or if matrix difficulties are encountered. MEL will analyze all samples in accordance with standard protocols (MEL, 2003).

Table 15. Recommended methods for field measurements and for laboratory determinations.

Parameter	Method*	Holding Time	Preservation Method	Estimated Range(including detection limit)
Field Measurements				
Flow Velocity	WAS, 1993	NA	NA	0 – 9 ft/s
Temperature	(no EPA) / SM 2550B	NA	NA	0 – 30°C
Laboratory Determination				
Fecal Coliform (MF)	EPA 16-909C / SM 9222D	24 hours	Cool to 4°C; 0.008% Sodium Thiosulfate	<1 – > 5000 cfu/100 mL

Data Management Procedures

Temperature Modeling Using Qual2k

Field data measurements needed for stream temperature modeling are outlined in Table 16. For the purposes of this table, the column labeled "Ecology" means all efforts from EAP, including maintenance of long-term monitoring stations in the subbasin.

Table 16. Temperature Data Requirements.

		Model Requirement		Data Source		
	Parameter	**Shade**	**Qual2K**	**Ecology**	**Other Data Contributor**	**GIS**
Flow	discharge - tributary		x	x		
	discharge (upstream & downstream)		x	x		
	flow velocity		x	x		
	groundwater inflow rate/discharge		x	x		
	travel time		x	x		
General	calendar day/date	x	x	x		
	duration of simulation	x	x	x		
	elevation - downstream	x	x			x
	elevation - upstream	x	x			x
	elevation/altitude	x	x			x
	latitude	x	x			x
	longitude	x	x			x
	time zone	x		x		
Physical	channel azimuth/stream aspect	x	x			x
	cross-sectional area	x	x		x	
	Manning's n value	x	x	x		
	percent bedrock	x	x		x	

	reach length	x	x		x	x
	stream bank slope	x			x	
	stream bed slope	x	x		x	
	width - bankfull	x			x	
	width - stream	x	x		x	
Temperature	temperature - groundwater		x	x		
	temperature - tributaries		x	x	x	
	temperature - water downstream		x	x		
	temperature - water upstream		x	x		
	temperature - air		x	x		
Vegetation	% forest cover on each side	x			x	
	canopy-shading coefficient/veg density	x			x	
	diameter of shade-tree crowns	x				x
	distance to shading vegetation	x				x
	topographic shade angle	x				x
	vegetation height	x				
	vegetation shade angle	x				x
	vegetation width	x				x
Weather	relative humidity		x	x		
	% possible sun/cloud cover		x			
	solar radiation		x	x		
	temperature- air		x	x		
	wind speed/direction		x	x		

Data collected during this TMDL effort will allow the development of a temperature simulation model that is both spatially continuous and which spans full-day lengths. The GIS and modeling analyses will be conducted using four software tools:

Oregon Department of Environmental Quality's TTools extension for ArcView (ODEQ, 2001) will be used to sample and process GIS data for input to the Shade and QUAL2Kw models.

Ecology's Shade model (Ecology, 2003a) will be used to estimate effective shade along the mainstem of the East Fork Lewis River. Effective shade will be calculated at 50 to 100meter intervals along the streams and then averaged over 500 to 1000-meter intervals for input to the QUAL2Kw model.

The QUAL2Kw model (Chapra, 2001; Ecology, 2003b) will be used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw will be applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget described in Chapra (1997). Diurnally varying water temperatures at 500 to 1000-meter intervals along the streams in the basin will be simulated using a finite difference numerical method. The water temperature model will be calibrated to instream data along the mainstem of the East Fork Lewis River.

The USGS model VS2DI (Hsieh et al., 2000) will be used to evaluate the continuous groundwater temperature data for selected (influent) piezometer sites to estimate both the temperature and volume of groundwater discharge to the river during summer baseflow conditions. These flux estimates will be integrated with stream seepage run information to estimate reach-specific streamflow gains and losses for later inclusion in the QUAL2Kw model development.

All input data for the Shade and QUAL2Kw models will be longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments.

QUAL2K (or Q2K) is a river and stream water quality model that represents a modernized version of QUAL2E (Brown and Barnwell, 1987). QUAL2Kw is adapted from the QUAL2K model originally developed by Chapra (Chapra and Pelletier, 2003). Q2K is similar to Q2E in the following respects:

One dimensional. The channel is well-mixed vertically and laterally. Non-uniform, steady flow is simulated.

Diurnal heat budget. The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale.

Diurnal water-quality kinetics. All water quality variables are simulated on a diurnal time scale.

• *Heat and mass inputs*. Point and nonpoint loads and abstractions (withdrawals or losses) are simulated.

The QUAL2Kw framework includes the following new elements:

Software environment and interface. Q2Kw is implemented within the Microsoft Windows environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface.

Model segmentation. Q2Kw can use either constant or varying segment lengths. In addition, multiple loadings and abstractions can be input to any reach.

Carbon speciation. Q2Kw uses two forms of carbon, rather than BOD, to represent organic carbon. These forms are a slowly oxidizing form (slow carbon) and a rapidly oxidizing form (fast carbon). In addition, non-living particulate organic matter (detritus) is simulated. This detrital material is composed of particulate carbon, nitrogen, and phosphorus in a fixed stoichiometry.

Anoxia. Q2Kw accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.

Sediment-water interactions. Sediment-water fluxes of dissolved oxygen and nutrients from aerobic/anaerobic sediment diagenesis are simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.

Bottom algae. The model explicitly simulates attached bottom algae.

Light extinction. Light extinction is calculated as a function of algae, detritus and inorganic solids.

pH. Both alkalinity and total inorganic carbon are used to simulate pH

Pathogens. A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.

Hyporheic exchange and sediment pore water quality. Q2K also has the ability to simulate the metabolism of heterotrophic bacteria in the hyporheic zone.

TTools

TTools is an ArcView extension developed by Oregon Department of Environmental Quality (ODEQ, 2001) to develop GIS-based data from polygon coverages and grids. The tool develops vegetation and topography perpendicular to the stream channel and samples longitudinal stream channel characteristics, such as the near-stream disturbance zone and elevation.

Shade Model

Shade.xls was adapted from a program that was originally developed by the Oregon Department of Environmental Quality (ODEQ) as part of the HeatSource model. Shade.xls calculates shade using one of two optional methods:

ODEQ's original method from the HeatSource model version 6 (ODEQ, 2003).

Chen’s method based on the Fortran program HSPF SHADE (Chen, 1996). The method uses a slightly different approach to modeling the attenuation of solar radiation through the canopy (Chen et al., 1998a and 1998b).

All data will be assembled from Ecology field surveys and monitoring data. The model output from Shade is a model input to QUAL2Kw.

All continuous temperature data will be stored in a temperature database designed by Ecology that includes station location information and data quality assurance information. This database will facilitate summarization of the temperature data and create a data table to upload temperature information to EIM.

Groundwater Modeling Using VS2DI

VS2DI is a graphical public domain software package developed by the U.S. Geological Survey to simulate fluid flow and solute/energy transport within variably saturated porous media (Hsieh, et al, 2000). VS2DI can be used to analyze one- or two-dimensional energy or solute transport problems. The model will be used during this study to develop one-dimensional heat (energy) transport simulations for those piezometer sites where continuous groundwater temperatures were logged. These simulations will provide an estimate of both the temperature and volume of groundwater discharge to the river during summer baseflow conditions.

Fecal Coliform Bacteria

Data reduction, review, and reporting will follow the procedures outlined in MEL's Lab Users Manual (MEL, 2000). Laboratory staff will be responsible for internal quality control validation, and for proper data transfer and reporting data to the project manager via the Laboratory Information Management System (LIMS).

All water quality data will be entered from LIMS into Ecology's Environmental Information Management (EIM) system. Data will be verified and a random 10% of the data entries will be independently reviewed for errors. If errors are detected, another 10% will be reviewed until no errors are detected.

The project manager or principal investigator will validate the quality of the data received from the laboratory and collected in the field in reference to the measurement quality objectives described in previous sections. The review will be performed on a quarterly basis. Adjustments to field or laboratory procedures or the measurement quality objectives may be necessary after such a review. Clients and QA Project Plan signature parties will be notified of major changes. Data that does not meet MQOs may be approved for use by the project manager but this data will be qualified appropriately.

Elevated fecal coliform densities (>200 cfu/100mL) will be reported to the SWRO in accordance with the official notification procedure. All other data will be made available to the SWRO for disbursement after quality control and EIM are completed.

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using SYSTAT/SYGRAPH8 (SPSS, 1997), WQHYDRO (Aroner, 1994) computer software, and/or EXCEL (Microsoft, 2001) software.

A statistical model will be used to estimate daily, seasonal, and annual bacteria loading. The Statistical Theory of Rollback from Ott (1995) will be applied to the estimated distributions of bacteria to establish distribution statistics that meet the water quality criteria (i.e. geometric mean and 90^{th} percentile).

Enivronmental Information Management (EIM)

An EIM user study (EFLRTMDL) has been created for this TMDL study and all monitoring data will be available via the internet once the project data has been validated (the study name can be found on the front page of this QA Project Plan). The url address for this geospatial database is: http://apps.ecy.wa.gov/eimreporting. EIM will accept the daily maximum, daily minimum, and daily average temperature summary from a continuous temperature data set. All temperature data will be uploaded to EIM by the temperature field investigator once all data has been reviewed for quality assurance and finalized. All laboratory data for fecal coliform monitoring will be uploaded to EIM by the bacteria field investigator once the data has been reviewed and finalized.

Data Verification and Validation

Data Verification

Field and laboratory data will be verified and validated at the completion of the data collection period. Data verification refers to "the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements" (EPA, 2002). Field staff will verify *in situ* while MEL staff will verify all lab-based data. All verification done by lab and field staff will be documented.

Following data verification and validation, principal investigators will complete measurement quality assurance and control checks by comparing against the measurement quality objectives in Table 14.

Data Validation

Data validation refers to "the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set" (EPA, 2002). Principal investigators will validate data collected under the present QA Project Plan.

Continuous temperature monitoring data will be validated as real water temperatures by comparison with the paired air thermistor at each site to check for data ranges where the instream thermistor may have been recording air temperatures due to receding stream stage at the thermistor site. Pre and post study accuracy checks of all thermistors used for this study will identify any instruments that are not measuring within their manufacturer specified accuracy range. If a thermistor does not pass the post study accuracy check then the data affected by that thermistor will be adjusted by the average difference of the pre and post study results.

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